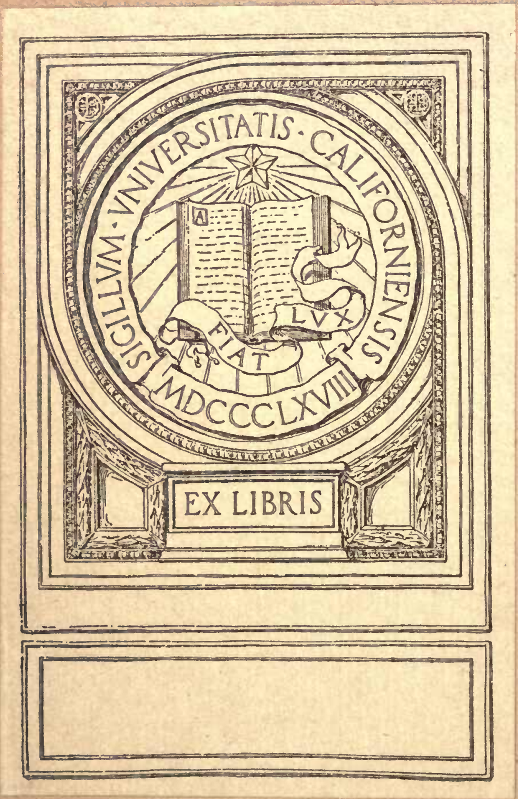
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# THE BRITISH AIRCRAFT INDUSTRY

# THE BRITISH AIRCRAFT INDUSTRY

## ITS INDUSTRIAL AND COMMERCIAL POTENTIALITIES

UNIV. OF
CALIFORNIA

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## *FOREWORD*

A GREAT new industry has been developed by war conditions so rapidly and so quietly that few perhaps realize how wonderful that development has been, and how great a factor in our lives flying is destined to become in the near future.

With the object of giving business men some idea of the progress of the aircraft industry, a section devoted exclusively to it was published with the April issue of the Imperial and Foreign Trade Supplement of *The Times*. No attempt was made to deal exhaustively with the subject: the intention was rather to interest the general reader in probable developments than to weary him with technical detail. In short, the section was not written for the expert, but for the average business man, whose interests, though not directly concerned with the aircraft industry, can scarcely fail to be affected by this new and wonderful means of transport.

At present no one can predict with certainty the direction in which the aircraft industry will develop, but just as the potentialities of the automobile and all that it meant to civilization were in the early days only dimly recognized by the most far-seeing, so the future of flight holds out almost illimitable possibilities that may revolutionize many of our accepted methods much sooner than we now anticipate. It is well that we should accustom ourselves to " think in terms of aircraft " before rather than after the revolution has happened.

This country lost a great opportunity through its conservatism and its reluctance to welcome the automobile and facilitate the establishment of the motor industry. The long start that foreign competitors gained handicapped our motor engineering firms for years. It is vitally important that history should not repeat itself: we must exert every possible effort to gain and keep not only supremacy in the air, but also supremacy in the airship industry.

The publication of the Aircraft Section in the Imperial and Foreign Trade Supplement led to so urgent a demand for that paper that the edition was sold out in a few days, and at the request of many who were disappointed in their desire to obtain a copy, arrangements have been made for republication in book form.

It only remains to point out that the book now presented is not the work of any one author. An attempt was made to secure the co-operation of the best authorities on every branch of the subject. Mr. C. G. Grey, the editor of *The Aeroplane*, not only contributed the two chapters entitled "The Problem of Flying" and "The Development of the Aeroplane," but gave us the benefit of his wide knowledge of the subject generally. "The Aerial Engine" was written by Lieut. W. E. Dommett, R.N.V.R. "Science in Aeronautics" was contributed by Mr. A. E. Berriman, chief engineer of the Daimler Company. Captain A. J. Swinton, late of the Royal Engineers, wrote on "The Flying Boat" and "The Commercial Potentialities of Flying," and Mr. Claude Grahame-White undertook "Flying as a Sport." "Fuel Supply" was contributed by Mr. J. T. Smith, editor of *The Petroleum World*. "The History and Use of Airships" was written by Mr. W. L. Wade. Mr. Ernest Allen wrote the chapter on "Kite Balloons and Parachutes." Mr. R. Borlase Matthews was responsible for the chapter on "The Materials of the Aircraft Industry," and Mr. Bernard Isaac for the chapter on "The Future of the Aircraft Industry." It naturally fell to the Legal Editor of *The Times* to contribute the chapter on "The Law of the Air."

Some of the contributors prefer to remain anonymous: to them, and to all who gave advice or assistance in a task rendered somewhat difficult by the exigencies of war and the ever-present anxiety not to reveal by inadvertence anything that could "comfort the King's enemies," are tendered the grateful thanks of

THE EDITOR OF "THE TIMES"
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# *The Problem of Flying*

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# *The Problem of Flying* I

IT is probable that ever since the dawn of human intelligence the problem of flying has been more or less of an obsession with man, and we of the present generations should be thankful amidst all our multitudinous troubles for having had the privilege of seeing that problem partially solved.

One uses the word "partially" advisedly, for though, in these days of aeroplanes which travel at speeds approaching 150 miles an hour, it might seem to the uninitiated that the whole solution of the problem had been found, we have in fact only recently reached the stage at which we are able to experiment under proper conditions—that is to say, in the air itself.

The middle-aged man of to-day can remember the time when a speed of a mile a minute was considered the ultimate attainment in human locomotion. Such speed was only reached by railway trains. Younger men can remember the coming of the motor-car, which actually attained speeds of 100 miles an hour and gave hopes of crowding two miles into the minute. Certain cars were even credited with covering a single mile, with a flying start, in half a minute. To-day there are children of the intelligent age who cannot remember a time when man could not fly, and two miles a minute is now a very ordinary speed for aeroplanes. Enthusiasts look forward confidently to a speed of 180 miles an hour, and doubtless in due course we shall cover three miles a minute through the air as a matter of everyday travel. For the dream of the enthusiast to-day is always the commonplace of to-morrow or the day after.

Yet speed alone by no means solves the problem of flying, and it is significant that the idea of speed in the matter of flying does not seem to have held so important a place in the early imaginings of man as it does in these days of commercial hustling. The earliest idea of flying seems to have been that the ability to fly conferred unlimited power on its possessor.

Thus we find in all ages and in all countries that angels or the more powerful of their opposites were endowed with wings. In Assyrian and Egyptian sculptures we find winged lions, winged bulls, winged sphinxes, all indicating power. It is only when we come to the more civilized and commercialized nations that we find the ability to fly associated particularly with speed. The Persians, an essentially commercial nation, had their legends of magic carpets which conveyed their owners rapidly from place to place. The Greeks, a still more commercial and civilized people, had in their winged Mercury the messenger of the gods.

On the other hand, the winged horse of the Greeks, Pegasus, was not associated with speed but with altitude—flights of the mind. And in the early Teutonic legends of winged horses we find the idea of power over enemies rather than of speed.

In the light of our present knowledge of the problem of flying, these early ideas on the subject are distinctly interesting, as presaging the uses to which our modern aircraft are being and will be put. It is possible to find an analogy between utilitarian conception of flying, as understood by the Persians and Greeks, and the intentions of the Civil Aerial Transport Committee, established early in 1917, with Lord Northcliffe as chairman. One important purpose of this committee is to create magic carpets for the use of enterprising merchants after the war, and to organize a proper service of winged Mercuries for the rapid conveyance of messages. This, however, is only one part of the problem of flying with which the Civil Aerial Transport Committee will have to deal.

Let us now hark back to the early days when flying passed the legendary period and became a problem subject to practical experience.

Obviously, man's first effort was to imitate the birds and to propel and support himself by means of wings attached to his arms. Many were the attempts in this direction. Icarus may have been a living experimenter, and not merely a personification of legend. Very probably, like sundry people in the

Middle Ages, he actually launched himself gallantly from a cliff or tower, and was killed.

In this connection it is worth while to recall the ingenious Scottish monk who constructed for himself wings made of cock's feathers, and projected himself in the presence of an admiring crowd from the battlements of the local laird's castle. Fortunately for him he fell into the kitchen-midden, or dung-heap, as the more brutal Saxon would call it, and escaped with a broken leg. As excuse for his discomfiture he advanced the theory that the wings being made of cock's feathers it was natural that they should return to their proper *habitat*, and he reasoned that if he had had eagle's feathers he would have soared aloft as per programme. Eagle's feathers being difficult to obtain, his experiments were not continued.

One may say without fear of contradiction that his theories were not more unsound and his excuse for failure not less ingenious than those of many modern scientists who, having made a name in other walks of life, have proved singularly unsuccessful when they have tackled the problem of flying. It is in fact only a matter of a couple of years since a gentleman, with a high reputation as a scientist, after much calculation proved on paper and reported officially that an aeroplane of a certain type could not get off the ground. The amount of work involved apparently delayed his report to such an extent that it was received by the department concerned precisely when the impossible aeroplane was already doing very successful trial flights. And only a year or so later an aeroplane of the same design, merely improved in detail, had the temerity to fly across Europe from London and drop bombs on Constantinople. All this shows how far we are in our scientific knowledge from a complete grasp of the problem of flying.

Following on these early efforts at flapping wings came the partial solution of the problem by the brothers Montgolfier, who discovered that by making a very light globe and filling it with hot air it was possible to lift weights off the ground. This was followed very soon afterwards by the invention of the ordinary gas balloon. Both were French inventions, and it is of interest to note in these days that a captive balloon was used successfully as an observation post by the Army of the French Republic at the Battle of Fleurus.

As a natural consequence attempts were made to navigate balloons, and before the year 1800 several inventors attached paddles, or long sweeps made of a light framework covered with fabric, to the cars of balloons, and tried to row them through the air. These efforts proved unsuccessful, but they showed the direction of progress towards the airship of to-day.

Simultaneously, experiments were in progress which led directly to the aeroplane as we now know it. Sir George Cayley, an English baronet, conceived the idea of a machine with fixed wing, which would lift simply by being propelled through the air. His experiments led him to discover a wing-shape very similar to that in use to-day—that is to say, one with a curved top and a somewhat flatter lower surface. These wings he attached to a body with a tail at the end, not unlike a modern monoplane. He carried out numerous experiments with models which were allowed to glide to earth from a height, and were induced to perform much as present-day aeroplanes perform when descending after the engine has been stopped.

Sir George Cayley even went so far as to invent an engine with which he hoped to drive the machine. In those days—the year 1808, to be precise—little was known of steam and nothing of petrol, and he hit on the brilliant idea of using gunpowder, firing it from a species of elaborate revolver, so that he actually had the germ of the idea of the internal combustion rotary engine. It is said that he completed the machine, and then induced his coachman to try it in a run along the ground, but that the man lost his nerve as soon as the explosions started, and jumped out, thus wrecking the machine.

Thereafter the problem of flying languished for a period. A few enthusiasts experimented with gliders—that is to say, aeroplanes without engines, launched from high places. One or two made efforts to lift aeroplanes from the ground by means of steam engines. Similarly, attempts were made to navigate sausage-shaped balloons with steam engines.

The gliding experiments were, in fact, most valuable. Professor Lilienthal, in Germany, made great progress, and discovered the way to many of the physical and dynamical laws governing the problem of flying. Unhappily he was killed in the course of one of his glides. In Austria Herr Igo Etrich found methods of rendering aeroplanes stable—that is to say uncapsizable.

In England Mr. Horatio Philipps worked out the section of wing which is commonly used to-day; Mr. José Weiss made valuable researches in the shapes of wings, the load per square foot which could be carried, and the problem of stability generally, and man-carrying gliders of his make travelled half a mile or so clear of the ground; Mr. J. W. Dunne, an army officer, also worked successfully on the stability problem. Sir Hiram Maxim, after experimenting with gliders, went so far as to build a large aeroplane with a steam engine, which actually left the ground under its own power, though not under control in the air ; this was wrecked after flying a few yards.

In America Dr. Montgomery designed a man-carrying glider, complete with proper control of the wings, tail, and rudder, like a modern monoplane. This was dropped from a balloon on many occasions with success, till one day the pilot died in the air, apparently from heart failure. Dr. Chanute, an Americanized Frenchman, an engineer of high repute, when over fifty years of age, also made many gliding experiments. His later experiments were made in conjunction with two brothers named Wilbur and Orville Wright, who had for some time been working on their own account with gliders.

From this conjunction of ideas grew the first real flying machine, the Wright biplane, which first left the ground, piloted by Mr. Orville Wright, on December 17, 1903.

It was the invention of the petrol motor which solved the most important part of the problem of flying. Though much was already known concerning the proper shapes of wings and of the air-screws necessary to propel the wings and body through the air, there had been no way of getting the machine off the ground. In France, the home of the petrol engine, many attempts were made to lift aeroplanes by means of petrol engines before the Wrights flew, but the existing engines were all too heavy, and because the motor-car trade was doing very well with them as they were it was not worth anybody's while to try to lighten them.

The Wrights, however, built their own engines with their own hands for their own purpose, and made them very considerably lighter than those of their contemporaries. Also, instead of expecting the engine to drag them off the ground, they launched their machine into the air by means of a catapult arrangement which propelled it along a rail, so that the engine had only to hold it in the air and not to get it there. Once in the air various equations of the great problem of flying could be solved, and thus still further progress was made.

Mr. Wilbur Wright came to France in 1908 and astonished Europe by his mastery of his machine, for he was able to remain in the air for an hour or so at a stretch, whereas the French experimenters were only able to scramble round a big circuit for a few miles at a time. Then the leaders in France were the Voisin brothers, with whom Mr. Henry Farman was co-operating, M. Santos-Dumont, and M. Blériot. In England the Short brothers were at work in co-operation with the Hon. Charles Rolls, Mr. Frank McClean, Mr. J. T. C. Moore-Brabazon, and a few more enthusiasts. Mr. S. T. Cody was experimenting alone at Farnborough and Mr. A. V. Roe at Brooklands motor track. Both the latter left the ground for short distances before the end of 1908.

In all cases progress was hampered by lack of suitable engines. The success of the Wrights, however, set people thinking along new lines, or showed them errors in their fixed ideas. The Wright machine was taken up in Germany officially, and it was introduced to England by Mr. Griffith Brewer, an old friend of the Wrights, an amateur balloonist of long experience, and himself the first Englishman who ever flew, having been taken up as a passenger by Wilbur Wright, but in England no official attention was paid to flying.

In consequence of all this activity in 1908 the problem of flying came much nearer solution in 1909. M. Levavasseur, a brilliant engineer, designed the Antoinette engine, the lightest thing of its kind in the world, and the Antoinette monoplane, the most beautiful aeroplane that has ever existed. At the same time M. Anzani, a maker of bicycle motors, built a rough, but very light, engine for M. Blériot. There ensued a duel between M. Latham, of the Antoinette firm, and M. Blériot as to who should be ready first to fly across the English Channel, and M. Blériot succeeded on July 9, 1909, winning the *Daily Mail* prize offered for the flight. In this manner the problem of over-sea flying received its first investigation.

In August of the same year a great aviation meeting was held at Reims, and here the second great aeronautical revelation appeared, the most remarkable since the Wright biplane.

The brothers Séguin produced the famous Gnôme rotary engine. It was about half the weight per horse-power of any other engine, and in spite of its abnormal appetite for petrol and oil it was so light in itself that anything in the shape of an aeroplane could be coaxed off the ground by it.

With Gnôme engines Mr. Henry Farman on a biplane of his own build and M. Paulhan on a Voisin biplane put up extraordinary performances, remaining in the air for three or four hours at a stretch without alighting. Here was the real opportunity for studying flying. A man could take an aeroplane off the ground, and, instead of watching every moment for a landing-place, he could watch the behaviour of his machine, and so learn something of the problem to be solved.

Thenceforward progress was rapid, despite the apathy of Governments and peoples alike, with perhaps the sole exception of Germany. In 1909 a fast aeroplane did 50 miles an hour. In 1910 60 miles an hour was fairly common. In 1911 over 85 miles an hour could be done. In 1912 people talked of 100 miles an hour with less astonishment. And in 1913 two French pilots, one on a Deperdussin monoplane and the other on a Hanriot monoplane, each covered over 120 miles in an hour round a 10-kilometre circuit. Allowing for slipping out and slowing down at corners, their speed must have exceeded 140 miles an hour on the straight stretches.

It must be remembered that these were purely freak racing machines, incapable of carrying a big load or of climbing to any considerable height, but the freak performance of yesterday is always the standard performance of to-morrow, so that their 140 miles an hour speed may be taken as a very probable travelling speed of the future.

Just in the same way M. Paulhan's London-to-Manchester freak flight for the *Daily Mail's* £5,000 prize, in 1910, is an ordinary journey between breakfast and lunch for any Service pilot to-day. M. Blériot's cross-Channel trip of 1909 is performed many times daily in the ordinary course of business in these times, some pilots doing the journey twice or three times in the day. Also, the famous "Circuit of Britain" course, covered with so much trouble and at so much risk by Messrs. de Conneau, Védrines, Cody, and Valentine, in the race for the *Daily Mail's* second £5,000 prize, is now an ordinary itinerary for any middle-aged General Officer of the Royal Flying Corps making a tour of inspection by air.

Thus far the problem of flying has been solved. The 100-mile-an-hour aeroplane is able to fly in almost any wind, and is only kept on the ground by thick fog, by very heavy rain, by snowstorms, or by a gale. High speed is necessary because, if one has to fly against the wind, the speed of the wind over the ground has to be subtracted from the flying speed of the aeroplane. Thus, if a 100-mile-an-hour aeroplane has to fly against a 50-mile-an-hour wind, its speed over the ground will be about 50 miles an hour, because for every 100 miles it flies it will be blown backwards 50 miles. It is exactly like a man walking from bow to stern of a steamer. If he only walks at the steamer's speed he will remain stationary opposite a point on the shore. Contrariwise, if an aeroplane flies with the wind the wind's speed is added to the machine's speed, and the aforementioned aeroplane will cover the ground at 150 miles an hour.

Thus it is evident that if the aeroplane is to become a regular passenger vehicle it must not do less than 100 miles an hour, because if it meets any wind above 50 miles an hour its speed will be less than that of a train. Fifty-mile winds are not uncommon at high altitudes, and therefore it is obvious that the more the speed of the aeroplane of the future exceeds 100 miles an hour the greater will be the use of the aeroplane as a vehicle. This is part of the problem still to be solved.

The practice of flying has also been helped largely in reaching its present stage by the solution of the problem of stability. In the early days an aeroplane which heeled over past a certain angle, or dived too steeply, or dropped its tail too low, became uncontrollable and was doomed to destruction. To-day the ordinary aeroplane, as distinct from the acrobatic fighting machine, is as stable as a lifeboat. It can be thrown into any position, upside down, sideways, head first, or tail first, and it will always come back to its proper flying position if left alone with room enough between it and the ground in which to right itself.

Most of the accidents of which one reads such shocking accounts occur because the pilot makes a mistake too near the ground for the machine to recover itself.

Already man is able to fly better than the birds. The aeroplane gets off the ground with a shorter run, in proportion to its size and weight and speed, than any bird. It flies very much faster than the fastest bird. It can fly in weather which no bird would face. It can fly greater distances without alighting than any bird can cover. It can fly to greater heights than any bird can reach. These statements, strange as they may seem, are proven facts.

Nevertheless, the problem of flying is far from being solved. Many improvements are wanted in aeroplanes before we can say we have reached our limit of development.

At present we use far too much fuel for

the distances which we cover, and in this direction we have much to do in improving the efficiency of engines. Although we have reduced the 1908 engine-weight of 10 lb. or 15 lb. per horse-power to less than 2 lb. per horse-power, there are still hopes of getting down below the old ideal of 1 lb. per horse-power. Every pound saved in the engine, or elsewhere, either in the structure of the machine or in the fuel carried, means that an extra pound of passenger or cargo can be carried, or that the distance flown without a stop can be increased by the distance covered in using a pound of fuel.

Then there is the problem of making aeroplanes fireproof, for fire in the air is the greatest, though happily not the most common, of all the dangers of flying. This may be done by using heavy fuel oils, which only ignite under special conditions and will not burn in the open as petrol does. Some people talk of using ammonia turbines instead of oil fuel. Others think only of means of preventing ordinary petrol from catching fire accidentally while in the air.

Another problem is the discovery of new materials. Some substance as elastic as wood, as strong as steel, and lighter than aluminium would aid the aeroplane designer considerably in making machines lighter and stronger.

As to navigation, also, there are many discoveries to be made. A safe method of landing in a fog is needed. A new light which would pierce fog as sunlight pierces it, without reflecting from it, would help. An instrument to indicate height above actual ground level, and not merely barometric height, is needed and has still to be found. Another instrument required is one to indicate speed over the ground.

Important discoveries which all help to solve the problem of flying are being made almost daily, but we are still far from the ultimate development of the aeroplane.

Of the airship one need only say that, apart from limited war uses, it has little future as an aid to trade, until and unless a non-inflammable gas as light as hydrogen can be discovered.

*The British Aircraft Industry*

## *Science in Aeronautics*

## Science in Aeronautics

## II

THE reduction of aeronautical knowledge to system has been a process of some difficulty, and, if the starting-point of the science be referred back to the reversed manuscripts of Leonardo da Vinci (fifteenth century), one occupying considerable time. Francis Lana, a Jesuit priest who lived in the latter half of the seventeenth century, possessed an accurate knowledge of the primary aerostatic law of buoyancy by displacement, and was, perhaps, the first to suggest aerial navigation by balloon, but as a proposition in practical aeronautical engineering his copper globes exhausted to a high degree of vacuum would have collapsed for a certainty. From neither of these dates, therefore, can we properly commence a study of science in relation to aeronautics.

It is necessary for convenience of treatment to separate aerostatics from aerodynamics in any record of aeronautical science, because in so far as the former has related to the development of the balloon and its self-propelled variant, the airship, it has made for itself a history that is almost entirely independent of the development of the aeroplane.

The discovery of hydrogen by Cavendish in 1766 inspired the ingenious Dr. Joseph Black to blow hydrogen-filled soap-bubbles for the great edification and doubtless greater amusement of his class a few years later, but had no influence whatever on the invention of the first practical balloon by the brothers Montgolfier in 1782. Science, as Sir Dugald Clerk so lucidly explained in his "Trueman Wood" lecture, recently delivered before the Royal Society of Arts, has complementary purposes, one being to discover new things and the other being to explain things that exist. In the case of the Montgolfier experiments, it was some little while before the scientists of the day arrived at the knowledge that "Mr. Montgolfier's gas" was merely hot air and that the ascensional properties of his balloon were due solely to the reduction of atmospheric density inside the envelope by the expansion of the air produced by the fire on the grate underneath its orifice. Hydrogen was applied to balloons in 1784 and coal gas in 1821. For the rest, the development of the science of aerostatics has been mainly related to mechanical engineering as applied to "lighter than air" aeronautics, to the realm of aerial navigation, as such, and to the science of aerodynamics, which it also shares with the aeroplane.

The discovery and explanation of phenomena associated with the motion of bodies in air, which is comprehended by the science of aerodynamics, extends roughly over a century, for it was in 1809 that Sir George Cayley, often referred to as the father of aerodynamics, wrote the articles in Nicholson's *Journal* and the *Philosophical Magazine* that entitle him to this dignity. The articles in question have been reprinted by the Aeronautical Society in the admirable series of small volumes known as the "Aeronautical Classics." Sir George, whose sound theories, lucidly expressed, left little excuse for wrong thinking in those who followed him, was a true pioneer, for he designed and constructed an aeroplane with which he would undoubtedly have attempted to fly had he been able to secure a suitable engine. He lived, of course, in the early era of steam engines.

Aerodynamics has proved itself to belong primarily to inductive philosophy, for although there is perhaps no branch of applied science that has afforded more scope for the pure deductive logic of the mathematician, the practical value of such calculations is worthless unless the premises have been established in the light of experimental research. It has taken an immense deal of effort to make this lamp shine brightly, and, indeed, it still casts many shadows; nevertheless, the supply of its oil and the trimming of its wick, which received but intermittent attention during most of the nineteenth century, have obtained the consecrated service of many neophytes during the last thirty years, and its present brilliance is to their everlasting credit and not less to the renown of England.

The fundamental problem of aerodynamics

is that of the force on a flat plate facing the wind. Its first variant is produced by inclining the plate at an angle, while the further special field of research is that of a thin plate moving edge on. The British figures of reference under the first heading are those provided by Dr. T. E. Stanton from his researches at the National Physical Laboratory. Expressing the relation of the various factors involved by the fundamental equation:

$$\text{Force} = \text{Cp Av}^2$$

Where p is the density of the air, A is the area of the plate, and v is the relative velocity of its motion in the air, Dr. Stanton found the following value for the constant C:

Small plates, $C = \cdot 507$
Large ,, $C = \cdot 62$

Subsequent experiments have provided corresponding data for many special cases, such as perforated plates, plates in tandem, honeycomb radiators, wires, struts, and the like.

Experimental research to determine the constants for an inclined flat plate was started by Langley in America about 1891, and his two contributions to the Smithsonian Institution at Washington, entitled "The Internal Work of the Wind" and "Experiments in Aerodynamics," were for a considerable time the principal text-books of early modern students of the science.

The particular and difficult case of the edgewise moving plate was studied with considerable perseverance by Zahm, who provided the minimum value ·0000082 for the coefficient k in the expression

$$\text{Force} = kA^{\cdot 93}v^{1.86}$$

In the use of this coefficient both sides of the plate are included in the numerical value assigned to the area A, and the form of the equation itself differs slightly from that originally published by Zahm himself, having been so modified by Lord Rayleigh in order to give it the true dimensions of a force.

These fundamental data, while not often directly applicable to the precise problem of practical aircraft design, provide essential points of reference in the growing field of knowledge, and, indeed, the true significance of the resistance constant determined by experimental research for objects of special shape, such as the gas vessels of airships and the wings of aeroplanes, would be unintelligible without this carefully prepared foundation.

Lilienthal was one of the first to investigate by means of scale models the properties of the cambered aerofoil and to point out its much superior " efficiency " of lift : resistance ratio as compared with the flat plate. This advantage is due to the resultant force vector on a cambered aerofoil being inclined forward from the normal to the chord as a consequence of the unequal distribution of pressure over the leading and trailing portions of the surface produced by the cyclic disturbance that exists in the vicinity of the leading edge of any inclined aerofoil in flight. In the triangle of forces that this forwardly inclined vector makes with the normal, the third side is a force vector parallel to the chord and directed up wind ; it was for a long time known as Lilienthal's tangential in the tables of aerofoil constants that resulted from his researches and from those of subsequent investigators. To-day, the complete analysis of a wing section provides a graph of its lift co-efficient and lift resistance ratio over a full range of angles, and may even be carried to the extent of exploring the distribution of pressure over the upper and lower surfaces. The former information is absolutely essential to the aeroplane designer, the latter to the designer of aerofoils as such. The research that provides accurate information of this kind is the work of trained researchers and involves elaborate apparatus.

Preliminary investigation of such problems by means of full-size flying machines is obviously too costly, besides being insufficiently accurate, and the foundations of experimental aerodynamics have been laid by experiments with carefully prepared small-scale models. On account of the turbulence of the atmosphere, it is not possible to do much out of doors, and Lanchester's early scientific experiments with model gliders is all the more noteworthy on that account. They led to the publication of his two-volume treatise on Aerial Flight in 1907 and thereby provided students with a much-needed text-book on aerodynamics, rendered all the more valuable by the author's natural lucidity of expression and comprehensive treatment of the theory of the subject. In the interlude between the work of Langley and the appearance of the first Technical Report of the Advisory Committee for Aeronautics, Lanchester's "Aerodynamics" occupied a position of unique importance among the literature relating to the science of aeronautics.

The prestige of England in this science, so ably founded by Cayley over a hundred years ago and carried on by many subsequent students, and notably by the members of the Aeronautical Society, founded in 1866, has owed much to the formation by the Prime Minister in 1909 of the Advisory Committee for Aeronautics. This Committee was so constituted as to be responsible direct to the Premier, and its deliberations determined the broad character of the research programme carried out with small-scale models at the National Physical Laboratory, and with full-sized machines at the Royal Aircraft Factory. To those who laboured long and diligently in both places during the years preceding the war, the country owes a debt of gratitude that is scarcely appreciated at its proper magnitude. The private research of constructors was an important ancillary to the building up of the science, but it lacked breadth and thoroughness by comparison, firstly because its purpose was necessarily related, in the main, to the immediate solution of daily difficulties ; and secondly because the pre-war support extended by the Government to the aircraft industry was on such a parsimonious scale as to prevent constructors who were dependent for their living on their orders from undertaking anything very ambitious in the way of pure research into fundamental problems. The men associated with the industrial side of the movement were, for the most part, inventors and designers, rather than discoverers and researchers, and their aims and ambitions essentially centred about the production of machines that would fly. That there is a fundamental difference in function between the workers in these two fields has been very clearly pointed out by Sir Dugald Clerk in the address to the Royal

Society of Arts above mentioned, and the recognition of this fact is one of essential significance in the study of the growth of aeronautical science.

To all intents and purposes, Sir George Cayley indicated the essential constructional elements needed for the control of the aeroplane in flight, and the sequence of intrepid pioneers who followed Lilienthal's lead disregarded entirely the fact that death was the penalty of failure. Their determination to work out the practical problems of aerial equilibrium in what they deemed to be the only practical way, rose sublimely unconscious of the thought of personal risk, and the history of mankind has no braver romance than is afforded by the biographies of these men who insisted on learning to fly in the air. Perhaps no minor incidents succeeded in throwing their unostentatious bravery into such relief as the unsympathetic reception which was accorded to Professor Bryan's publicly made suggestion that further flying experiments might be abandoned pending the mathematical solution of the stability problem.

Those who knew the true worth of the progress that the pioneers had made appreciated it too well to take such a thought seriously; nevertheless, aerodynamics is a science in which mathematics plays an important part, and in the particular problem of aeroplane stability it attains a position of singular significance. In this department, too, much credit is due to Professor Bryan for the mathematical treatise on the subject, which he has worked out with great labour and in which he has provided the forms of the equations applicable to the principle fundamental cases. The aeroplane in flight is a body possessing six degrees of freedom, and the equations in consequence often assume alarming proportions. That they have been of practical value, however, is undeniable, and the credit of making them so is in a large measure due to the late Captain E. T. Busk. The peculiar genius of this young officer was known to few, but by them it was undoubted. He seemed destined to be one of the world's great minds, but fate, in the form of a tragic fire that broke out while he was flying a stable aeroplane of his own design, determined otherwise.

Any account of science in aeronautics condensed into the space of a review such as this is necessarily sketchy, but it would be definitely misleading were it to ignore the part that has been played by the aero engine and by the materials of aero construction. It is convenient to deal with the aero engine first, because the science of its development is in a large measure concerned with the choice of material, and therefore affords a convenient introduction to that phase of the subject. Leaving aside the great field of internal combustion engine research, explored successively by Barnett, Beau de Rochas, Otto, Clerk, Robson, Atkinson, and Diesel, for more than half a century, the science of the aero engine, as such, may be broadly reviewed under three headings:

(a) Type design.
(b) Cylinder research.
(c) Materials of construction.

Fundamentally, the problems focus upon

weight saving, and to this end the most phenomenal advance on pre-aeronautical practice was undoubtedly made by the design of radically new types, among which the most notable is the radial rotary system pioneered by the Gnôme. The disposition of the cylinders in one plane effected a shortening of the engine as a whole, and a consequent saving of weight on two of the heaviest units, the crank-chamber and the shaft. It was a thoroughly scientific departure from orthodox method, for while the engine thus produced would have been inconvenient to the point of being impracticable on a motor-car, its shape was thoroughly acceptable to the aeroplane designer. That the radial engine had imperfections goes without saying, and one of its most serious limitations was its low power. The number of cylinders in one plane was increased from five to seven, nine, and even eleven, but it was a considerable time before the most popular models exceeded 100 B.H.P. Under these circumstances, the simple vee variants of the standard straight line four- and six-cylinder engines had the high-powered field to themselves, and for several years they have held an unassailable position because such motors can be water-cooled for the purpose of enabling each individual cylinder to develop maximum power. The fundamental experience from which this phase of the subject expanded was gained by some investigators in the racing days of motoring, but others also undertook the development of the cylinder unit strictly from the aeronautical standpoint, and evolved much useful knowledge that is still in process of systematization. Notably has this research improved the performance of air-cooled engines to a point at which their direct competition with water-cooled engines of all sizes is assured and their victory on a weight per h.p. basis more than probable.

Given a type of engine that occupies least space, fitted with cylinders that develop most power, any further saving of weight must come from the use of the specifically strongest material in its construction. By specific strength is meant strength in relation to density, and judged by this standard a high-quality steel is lighter than aluminium. For some purposes, however, aluminium is preferable because of its relatively high thermal conductivity, and by the same reasoning copper, although a material of high density, may, when suitably used, be lighter than aluminium itself.

In the construction of aeroplanes and dirigibles the principle of specific strength is of even greater importance, because the large size of the machine and multiplicity of its parts impose a severe penalty in the aggregate increment caused by many small individual errors. Hitherto, timber has been specifically stronger than metal for aeroplane spars and the like, but alloys of aluminium predominate in airship construction.

In both there has been a great field for the development of fabric and other incidental materials that are hardly used elsewhere in engineering.

In connection with this subject, it would be not only unjust, but ungracious, to omit reference to the science of inspection; for the Aeronautical Inspection Directorate, who by the nature of things are a much-abused body of men, unquestionably deserve credit for having elaborated a most important phase of aeronautical knowledge, even if they have not reduced it to system.

The problem of science in relation to the future of aeronautics continues to focus upon research, but as this subject will doubtless be reported upon by the Civil Aerial Transport Committee, which has been holding its meetings for some time past, it may be as well to await that issue before commenting upon the outlook. In common with other industries, that of aeronautical engineering will have to decide what use it will make of the facilities offered by the new Department of Scientific and Industrial Research, and no doubt a portion at least of the above-mentioned Committee's report will be aimed in that direction. One of the things much needed in this and other industries is the existence of a bureau of information from which practising engineers can obtain at short notice the latest information on points of technology either directly concerned with or allied to their work, and as this is now specifically one of the preliminary objects for which research associations may be founded with the approval of the new department, it is to be hoped that many branches of the engineering industry may come to possess them.

In the preceding remarks nothing whatever has been said about the significance of meteorological research in relation to aeronautics. Although the practice of flying depends less and less upon the weather, systematic study of meteorology is of the very first moment to aeronautical development, but sufficient will have been said in this place if these brief remarks serve to ensure for this section of research the sympathetic appreciation that it deserves from all readers. When aerial transport is developed for civil purposes and a more numerous section of the public entrusts itself to the making of journeys by air, there will be less need to advocate and none whatever to excuse the expenditure of funds for this and other related purposes.

*The British Aircraft Industry*

# *The Development of the Aeroplane*

ALTHOUGH the first human flight on a power-driven aeroplane, free from control on the ground, was made by Mr. Orville Wright on December 17, 1903, it was not until 1908 that the aeroplane, as a more or less consistently navigable vehicle, really came into being. Consequently, in dealing with the development of the aeroplane that year must be taken as the starting-point.

In this chapter no attempt will be made to give a detailed history of flying as such ; the gradations will merely be indicated by which the aeroplane of the present day has developed from the first successful machines of 1908. The aeroplanes illustrated in the inset are those which are generally held to have initiated a fresh step in development, and to have been either the forerunners of a new type or to have been such an improvement on an existing type as to justify their claim to be considered a distinct step forward.

The first aeroplane with any claim to success was, as already stated, the Wright. The 1908 type was driven by a small four-cylindered, water-cooled engine, built by the Wright Brothers themselves. It was a biplane, driven by two large propellers, both actuated by chains gearing on the engine shaft, one chain being crossed—like a crossed belt on a lathe—so as to make its propeller revolve in the direction opposite to the other and thus give proper balance to the driving force. The pilot sat alongside the engine, and slightly in front of it, and there was a seat for a passenger in between, right in the centre, so that the balance should not be altered by the added weight.

Unlike modern aeroplanes, this machine had no horizontal tail behind the main planes, and so it belongs properly to what is known as the " tail-first " class, called by the French the " canard "—or " duck "—class, by reason of its long neck-like projection forward. The " canard " class was never successful, though tried in France by the Voisin Brothers and Blériot, and in England by Mr. H. C. Barber on the "Valkyrie." It was possible to make such machines fly, but they could never be made to steer properly. The "Valkyrie," the last of the class, died in 1913.

The Wright had vertical rudders aft, as in modern practice, and relied on the two big elevator-planes forward for its up-and-down steering. Its lateral, or rolling, movements, were controlled by warping, or twisting, the wings so that while the angle of the wings on one side was increased and gave more lift, the angle on the other side decreased and gave less lift, thus enabling the pilot to right himself, if he did not go too far over.

The pilot controlled the elevators with a lever on his left-hand side, and the warp with a lever on his right, while by moving the jointed top of the right-hand lever he also controlled the rudder. This complicated system of control was hard to learn, and Wright pilots were few.

In 1910 the Wrights fitted a horizontal tail at right angles to their rudder, and in 1911 they dropped the front elevators altogether, but thereafter the Wright machine practically ceased to develop further, and of late years little has been heard of it.

The peculiarity of the 1908 Wright was that it was launched by running along a rail. At one end of the rail was a pylon with a pulley at the top. A line was led over this pulley, from a heavy weight on the ground, down to the pylon end of the rail, along the rail to the outer end, over another pulley, and back along the rail to a little carriage on which the machine was mounted. When the line was pulled back to the carriage the weight was hauled to the top of the pylon. On releasing the carriage the weight fell down, hauled the carriage, and with it the aeroplane, along the rail, and gave the necessary speed to enable it to rise into the air. The carriage was, of course, left behind.

As aeroplanes developed, this catapult method of launching was discarded, and now all aeroplanes rise from the ground taking their own wheels with them. But for some years before the war the present writer consistently advocated that some analogous catapult method should be used for launching floatable aeroplanes (as distinct from seaplanes) from the decks of ships.

Almost contemporary with the Wright was the Voisin biplane. The Voisin Brothers, Charles and Gabriel, had been experimenting for some years, together with M. Blériot and Mr. Henry Farman, the experiments being assisted financially by Mr. Archdeacon and M. Henri Deutsch de la Meurthe. By the beginning of 1908 the Voisin biplane was flying very fairly, for on March 21 Mr. Farman flew 1¼ mile at Issy, near Paris, and made a turn, and on May 30 the late Léon Delagrange flew for nearly 8 miles at an aerodrome near Rome, capping this on September 21, 1908, by flying for 41 miles, round the military ground at Issy, without descending. Thus the machine was proved successful.

The Voisin was a big biplane, and, like the Wright, it had a front elevator-plane. But, unlike the Wright, it had a big box-kite tail on which the rudders were mounted. The wings also had vertical partitions, the whole theory of the machine being based on that of the box-kite. It had no lateral controls, the vertical partitions being supposed to keep it steady, which they did up to a point, but it was practically unflyable in any wind above a zephyr. The first machine had a 50-h.p. eight-cylinder Antoinette engine, and the later ones a 40-h.p. Vivinus, an ordinary motor-car engine, heavy but reliable.

When the famous Gnôme rotary engine appeared in 1909 the first of them was fitted to a Voisin biplane by M. Louis Paulhan, who, later on, won the *Daily Mail* £5,000 prize for the London-Manchester flight. On this Gnôme-engined Voisin M. Paulhan abolished all previous records for distance and duration at the Reims Meeting in August, 1909.

A notable feature was the fact that the under-carriage, the tail-booms, and much of the internal structure were made of steel tubing, and to-day steel tubing is coming more and more into favour. The machine was heavy and clumsy, and not till the rotary Gnôme engine was introduced in 1909 did it ever put up a respectable performance.

Thereafter various alterations in design were made, but the Voisin was never manufactured in numbers until 1915, when the firm brought out a big bomb and gun carrying biplane, strong and heavy, which, despite its comparative clumsiness, did useful work. This machine retained unmistakable Voisin features, especially in its tubular structure.

The elevator control of the Voisin was operated by a rod from the front elevator to a wheel in front of the pilot, which was pushed forward to push the nose of the machine down, and pulled back to pull it up, a perfectly natural motion, easy to learn. The rudders were worked by wires leading to a pivoted bar on which the pilot's feet rested. Pushing the right foot steered to the right, pushing the left foot steered to the left, also a natural motion. The Voisin may be set down as the father of all "pusher" aeroplanes—that is to say, machines with the engine and air-screw behind.

During 1908 M. Louis Blériot had been experimenting with monoplanes, in which he departed from his former co-operator's ideas by putting the engine in the nose of the machine with a tractor-screw in front of it. He also made a more or less fish-form or streamline body, with the tail and elevator planes fixed horizontally, and the rudder vertically at the rear end of it. This was the first successful "tractor" aeroplane, as opposed to the "pusher."

In 1908 M. Blériot achieved some success, but it was in 1909 that he really came to the fore. His "Type XI" machine is the prototype of all successful monoplanes. In this he incorporated the Wright idea of warping the wings to give lateral control, and so produced the first aeroplane to be thoroughly controllable in all directions. On the first of this type, with a 28-h.p. Anzani air-cooled engine, M. Blériot himself flew the Channel on July 25, 1909. So far advanced, in fact, was this "Type XI" model of 1909 that exactly the same design of machine, except for a few structural details, was the first to loop the loop as a matter of custom in 1912. After 1909, when fitted with Gnôme or Le Rhône rotary engines, the performance of the machine was greatly improved, and several of them were still in use in the early days of the war in 1914. Ultimately the type was killed by the need for high speeds, since the Blériot under-carriage, excellent for its purpose, could not be made so as to be pushed rapidly through the air.

In his monoplanes M. Blériot introduced the " stick " form of control, in which moving the control-stick forward or backward moved the nose of the machine down or up. Moving the stick to the right pushed the right wing down, moving it to the left pushed the left wing down. The rudder was worked by the feet, as in the Voisin. Thus a natural movement was given to all the controls, and a great step forward was made.

While these events were taking place in France little was done in England, but a young marine engineer named Aylwin Verdon Roe was experimenting under strictly limited conditions. Despite difficulties, he got off the ground on a " canard " type biplane in 1908, and during the autumn of that year proceeded to build a tractor triplane. By the summer of

1909 he had it completed, and in June flew it over Lea Marshes. His power plant was a 9-h.p. J.A.P. motor-cycle engine, the lowest power which has ever flown an aeroplane. It was also the first successful triplane.

The machine had warping wings, tail elevators, and a rudder astern. In general lines and arrangement it is the prototype of all the modern tractor biplanes and multiplanes. The control was by stick and rudder-bar, much as in the Blériot, and as now used on nearly all aeroplanes.

This little machine was considerably developed during 1909 and 1910, so that by 1910, with an eight-cylinder J.A.P. engine it had become a really good flying machine. Then Mr. Roe abandoned the triplane in favour of the biplane, which he fitted with a British-designed Green engine, of the vertical-cylinder type, once more setting a new fashion. Thereafter the triplane practically disappeared, till it was revived by British, French, and German designers during the war—chiefly by way of experiment, for it has never become an accepted standard type.

Considerable space has been devoted to these first four aeroplanes, because from them are derived in one respect or another all succeeding types.

While M. Blériot was developing his monoplanes, Mr. Henry Farman also dissociated himself from the Voisin Brothers, and began experimenting on his own account. The result of his experiments was first seen at the great Reims meeting in August, 1909, when his Gnôme-engined biplane appeared. Like the Voisin, it had a front elevator sticking out forward, but the vertical partitions had disappeared from the wings, though retained in the tail. The whole machine was built of wood, so that it was very much lighter than the Voisin.

Its most remarkable step forward, however, was the use of balancing flaps—usually called "ailerons," or little wings—let into the rear edge of the end of each wing. These ailerons were pulled down on one side to give that side extra lift, when the machine tilted down on that side. Thus the ailerons had the same effect as warping the wings, and, as it then became unnecessary to twist the wing itself, it became possible to build the whole wing structure as a fixed box-girder structure of wood and wire, lighter and stronger than was safe with a warping wing.

For this reason aileron control is used on all modern aeroplanes on active service.

The Farman biplane was fitted with the stick control used by M. Blériot, the stick working wires fore and aft for the elevator and laterally for the ailerons. A rudder-bar for the feet operated the rudder wires. Here we have the beginning of the modern idea of a "pusher" biplane.

Another great machine of 1909 was the Antoinette monoplane, evolved from the early experiments of MM. Gastambide and Mangin, and designed throughout by the famous engineer, M. Levavasseur, both aeroplane and engine. On one of these machines the late M. Hubert Latham only just failed to fly the Channel before M. Blériot. By the time of the Reims meeting in August it was in full working order, and during the last few days of the month there was a continual fight for the distance and duration "records" between Latham on the Antoinette, Paulhan on the Voisin, and Henry Farman on the Farman. The Antoinette was much the faster, but its engine always failed to hold out long enough to beat the others. Nevertheless, the Antoinette showed itself in other ways to be the finest flying machine of the period, and it has never been surpassed for beauty.

It was the first machine in which real care was taken to attain a proper streamline form in the body, and at the same time to make a proper engineering structure. The wings were orthodox king-post girders. The body was largely a box-girder composed of three-ply wood. The tail was designed like the feathering of an arrow.

Unfortunately, the internal structure of later machines was bad, and many broke in the air, with fatal results. The control was very difficult to learn. One wheel worked the warping of the wings, another worked the elevator, and there was a rudder-bar for the feet. Consequently these machines never became popular, and the last of them vanished in 1912. Nevertheless, the machine marked an epoch in that it was the first "eyeable" aeroplane, and it is an unvarying mechanical fact that a mechanism or an engineering structure which is fully developed and correct as a whole is also good to look at.

The year 1910 was somewhat bare as regards development, but it produced one distinct step forward—namely, the arrival of the tractor biplane, which is now the preponderating type in all countries.

The first machine of this type was designed by M. Bréguet, a rich French engineer, who had begun experimenting in 1908 or earlier. His first really successful machine appeared late in 1910. Early in the year he produced a primitive version of it, which was nicknamed the "Coffee Pot," being sheathed entirely in aluminium. This developed later into the type illustrated, which survived with minor alterations until the outbreak of war. During the war various Bréguets have appeared, both "tractors" and "pushers," and to-day the modern Bréguet is one of the best machines in the French Service.

The machine shown had many interesting features. It was almost entirely composed of steel tubes, covered with aluminium plates, leading the uninitiated to call it an " armoured war-plane," which it was not. The tail, which was one piece with the rudder, was carried on a huge steel universal joint at the tip of the fuselage, so that it swivelled up or down or sideways in answer to the controls. The wings had one enormous steel tubular spar, and consequently only one row of inter-plane struts. The controls were interesting. There was one wheel on the top of a pillar. Fore and aft rocking of the pillar controlled the elevator, rocking it sideways warped the wings, rotating the wheel operated the rudder. The arrangement was quite natural and might have become universal practice, but that by this date so many people could fly and all were used to the rudder-bar system.

The under-carriage had a wonderful oleo-pneumatic spring arrangement, which was highly satisfactory, and was the forerunner of many similar efforts, not yet perfected, which will come into their own in peace time when we can afford to carry a little extra weight on our great aerial liners.

The whole machine was enormously heavy, but it and its successors were fast, and great weight-lifters. In fact, a Bréguet of later date lifted ten (selected) passengers at once. Because of sundry minor defects in detail the machine never became highly popular, but it was certainly the first step towards the big tractor biplane of to-day. It is also of interest because a Bréguet seaplane was built very early in 1913 with a 200-h.p. Salmson engine, and thus was practically three years ahead of its time in ideas of engine power.

Reference has already been made to the Avro biplane. The first of these appeared late in 1910, with a little 35-h.p. Green water-cooled engine. It was a small machine, astonishingly lightly constructed, but it proved to be exceedingly strong. Some of the leading people in the Flying Services to-day learned to fly on it, and it made numerous cross-country flights, one to Brighton and back. In its essential principles it was identical with the modern tractor biplanes. It marked a distinct step forward in that it showed the way towards the small fast fighting biplanes of to-day, and also towards the bigger biplanes with fixed-cylinder, water-cooled engines.

The year 1911 produced two remarkable developments. The first was the abandonment by Mr. Henry Farman of the front elevator, and his adoption of elevator control on the tail alone, as was already the custom in monoplanes. The result was a curious-looking biplane retaining general Farman characteristics, but with the pilot and passenger sitting out in front of the machine on a contrivance resembling a ladder without any visible means of support.

These machines showed remarkable increase of speed over the older types, by reason of the reduction of head-resistance through the absence of the more or less useless big front elevator with all its booms, and struts and wires.

Later on the ladder was boxed in with a light framework, covered with fabric, somewhat as in the first Voisin, but without the elevator, and so became what is called a "nacelle," which is French for cradle. Thus the 1911 Farman became the forerunner of the "pusher" fighting machines with a gun in front, commonly called "gun buses."

The other remarkable step in 1911 was the monoplane produced by the brothers Edouard and Charles de Niéport, more commonly known as Nieuport. This machine had a very fat body, bluff in front and tapering well aft. The pilot and passenger sat close together right inside, with only their heads and shoulders visible.

Everything outside the machine was faired off to the utmost degree, so as to reduce head-resistance. The under-carriage was reduced to a remarkable extent, consisting only of three V's of steel tube, of streamline section, connected to a single longitudinal skid.

The result was a very fast machine, which, with only a seven-cylinder 50-h.p. Gnôme engine, attained a speed of about 70 miles an hour, and with the double-row Gnôme (fourteen cylinders of the 50-h.p. type, alleged to give 100 h.p., but really giving about 70 h.p.) it reached between 80 and 90 miles an hour. In the Gordon-Bennett race in the Isle of Sheppey the winner, M. Weymann, made an average speed of 79·5 miles an hour, so that, allowing for the corners, he must have been doing about 90 miles an hour on the straights.

The fat, streamlined, all-inclusive body of the Nieuport was distinctly the originator of the body design of the fast tractor biplanes of to-day.

A remarkable machine of 1912—a very busy year—was the biplane evolved by Mr. Maurice Farman, brother of Mr. Henry Farman. He had long been experimenting independently on lines half-way between those of the Voisins and his brother. The result represents the ultimate development of the machine with the front elevator. In the British military trials of 1912, with a 70-h.p. air-cooled Renault engine, it performed excellently, and it survived as a training machine till well on in 1916.

It was probably the most comfortable machine which has ever been evolved, and it was remarkably easy to fly, answering all its controls admirably. The deep nacelle gave the pilot excellent protection, and set a new fashion in nacelle design, which was developed in the " gun buses " of later date. On account of the long projecting horns which carried the front elevator it was nicknamed " the Mechanical Cow," and when Mr. Maurice Farman produced a later type without the front elevator and the horns, the new type was called " the Shorthorn," while the 1912 type became " the Longhorn."

During 1912 the Royal Aircraft Factory at Farnborough produced a notable tractor biplane, designed by Mr. Geoffrey de Havilland, one of the earliest experimenters in this country. This machine combined something of the arrangement of the 1910 Avro, something of the fuselage lines of the 1910 Bréguet, and a little of the Nieuport tail design, but the detail design was entirely Mr. de Havilland's own. It was very light for its size and capacity, and with a 70-h.p. Renault engine its performance was remarkable. Its speed was about 70 miles an hour, and it handled in the air and on the ground in a manner never before seen. It was the forerunner of a long line of R.A.F. designs, through all the range of B.E.'s, on to the R.E. series and the S.E. series.

It may be well to explain here that the initials B.E. originally stood for " Blériot Experimental," as M. Blériot was officially credited with having originated the tractor-type aeroplane. Later B.E. was taken to indicate " British Experimental." The subsequent development into R.E. indicated " Reconnaissance Experimental," these being big biplanes, with water-cooled engines and bigger tank capacity, intended for long-distance flights. S.E. indicates " Scouting Experimental," the idea being that fast single-seaters would be used for scouting. They are, however, only used for fighting.

Another R.A.F. series is the F.E., all large " pusher " biplanes, descended from the Henry Farman. The initials stood originally for " Farman Experimental," but now stand for " Fighting Experimental," the type being variants of the Vickers " gun bus."

Possibly the greatest achievement of 1912 was the little monoplane designed for the Deperdussin firm by M. Béchereau and M. Koolhoven, to compete in the Gordon-Bennett race at Reims. This was a tiny machine with a fourteen-cylinder 100-h.p. Gnôme engine. It won the race, covering 126½ miles in the hour—the first time a man had beaten two miles a minute for an hour on end. Allowing for corners its speed must have been well over 130 miles an hour on the straight, an uncommon speed even to-day.

Everything about the machine was streamlined to the utmost, even to the extent of putting a streamlined support behind the pilot's head. The under-carriage was reduced to two wheels, an axle, and four carefully streamlined struts. This machine was the forerunner of all the very high speed aeroplanes of to-day. It was also remarkable for having its fuselage built entirely of three-ply wood, built on a mould without any internal bracing. The three-ply fuselage was adopted in all German fighting machines in 1916–17, and its merits are slowly being recognized in this country.

Another remarkable development of 1912 was the Curtiss flying-boat, the first American contribution to development since the Wrights first flew. Mr. Glenn Curtiss, who won the Gordon-Bennett race at Reims in 1909, largely by personal skill, on a very primitive biplane, had succeeded in getting off the water in 1911 with a similar biplane fitted with a central pontoon-float instead of a wheeled under-carriage.

This he developed into a genuine flying-boat, consisting of a proper hydroplane boat with wings and engine superimposed. From this have evolved all the great flying-boats of to-day, and it is undoubtedly the ancestor of the great passenger-carrying ocean-going boats of the future.

The other type of sea-flying machine also came to maturity in 1912, when, after much preliminary experimenting, the Short Brothers, of Eastchurch, developed a proper sea-going biplane, fitted with twin floats in place of the ordinary under-carriage. This, with only an 80-h.p. Gnôme engine, was the first flying machine to prove its ability to get off or alight in anything of a sea, and to-day with 300 h.p. or more, it is able to face almost anything in which a vessel up to the size of a destroyer can travel.

Successors of this type have carried torpedoes and launched them successfully against enemy ships. They have patrolled steamer lines, and have escorted food convoys. They have sunk submarines, and they have bombed hostile positions over 100 miles from the sea. These Shorts were the forebears of the small, fast fighting seaplanes of to-day, having developed both upwards and downwards in the matter of size.

Yet another 1912 development was the German Taube-type monoplane. "Taube" means dove, and the type is so called because the wings are swept back and turned up at the tips like those of a pigeon. The originators of the type were Herren Wels and Etrich, in Austria, in 1908. Herr Etrich went to Germany and his design was taken up by Herr Rumpler. It was copied by various others, but the Rumpler-Etrich of 1912 was the first success.

This machine was designed to be inherently stable, that is to say uncapsizable. In this, to a great extent, the type was successful. If it had room to recover its proper attitude before hitting the ground it generally did so. Other designers, such as Mr. Dunne and Mr. Weiss in England, had striven likewise for inherent stability, but had failed to get past a certain point in development. The Taube went somewhat further, greater financial support being obtainable in Germany, and the 1912 type survived with modifications far into 1915, when it was succeeded by the big German biplanes, possessing more speed and carrying power. Inherent stability was ultimately attained, with less waste of power, by British designers.

In the Henry Farman of 1913 we find the "pusher" design crystallizing into its ultimate form. The whole machine has become neater and more compact. The nacelle shelters the pilot reasonably well. The tail, elevator, and rudder form an eyeable unit, and the general effect is more workmanlike and less spread-eagled. This type was ultimately combined with the " Shorthorn " Maurice Farman into a composite machine nicknamed the " Horace "—a jesting combination of Henry and Maurice—which was doing good service in 1917, as a means of training and aerial travel rather than as a fighting machine. The 1913 type was a distinct step towards the Vickers and F.E. gun buses.

Here we have a machine which marked a startling development. Mr. T. O. M. Sopwith, himself a brilliant pilot, Mr. Hawker, a clever Australian pilot, and Mr. Sigrist, Mr. Sopwith's chief engineer, produced early in 1913 a tiny tractor biplane, with an 80-h.p. Gnôme engine, which startled the aeronautical world by doing a top speed of 95 miles an hour, while possessing the ability to fly as slowly as 45 m.p.h. The result was obtained by skilful reduction of weight, by careful streamlining of external parts, and by close attention to wing design.

It was the first high-speed biplane, for hitherto monoplanes had always been considered faster than biplanes. All the high-speed fighting biplanes of to-day—" Scouts," " Pups," " Camels," " Bullets," " Dolphins,"

" Hippos," " Snipes," " Hawks," " Elephants," " Squibs," " Kittens," " Babies," " Schneiders," " Bats," and others with fancy names coined affectionately for them by their designers and pilots, descend in the strictest genealogical tree from the original " Tabloid," so called because it contained so much concentrated excellence.

Following soon after the " Tabloid," came a new Avro, which remains to-day one of the most remarkable of aeroplanes. A large two-seater, with only an 80-h.p. Gnôme, it put up a speed of well over 80 miles an hour. As a war machine early in the war it did excellently. Three bombed Friedrichshafen with success. To-day, with but slightly higher power, it is the best of all training machines. Among two-seater biplanes it marked as great an advance as did the " Tabloid " among single-seaters, and for the same reasons, careful lightening, without loss of strength, and careful streamlining.

Early in 1914 came the first genuine gun-carrying biplane, designed and built by Vickers (Limited). Obviously of Farman inspiration, or descent, it had a specially strong nacelle, to stand the working of the gun. With a 100-h.p. Gnôme, its speed was over 70 miles an hour. It was universally known as "The Gun Bus," and the name stuck to the whole class.

Another development of 1914 was the Albatros tractor biplane, with a six-cylinder vertical water-cooled Mercédès engine of 100 h.p. This was the ancestor of all the big German tractor biplanes up to the present day. It, and they, are descendants obviously of the Bréguets and Avros of 1910.

Just before the war the Royal Aircraft Factory produced an uncapsizable biplane nicknamed "Stability Jane." Her official title was the B.E. 2c, this being the third modification (c) of the second type of Mr. de Havilland's original B.E. When once off the ground the machine flew itself, and the pilot had only to keep it on its course. Though slow in speed and in manœuvring, the type was useful for certain definite purposes, and with further modifications it survives to-day, and does all that the Taube set out to do, with less waste of power.

Though various experiments had been made with aeroplanes with more than one engine, and though many were designed in 1914 which afterwards made good, the first to fly regularly and with consistent success was the twin Caudron, with two 110-h.p. Le Rhône engines. This may therefore claim to be the first twin-engined machine.

Closely following it came the huge Handley-Page biplane of 1916, with (at first) two Rolls-Royce engines of 250 h.p. each. Like everything else connected with the war, they have since gone up, and the power is now far higher. One of these machines in 1916 took a pilot and twenty passengers to a height of 7,000 feet, and in 1917 another flew from London to Greece and then bombed Constantinople.

The most noteworthy of the small machines of 1916 was the Nieuport biplane with the 90-h.p. and later the 110-h.p. Le Rhône engine. This was an excellent fighting machine, and a direct successor of the "Tabloid." It was remarkable for the curious V formed by the struts between the wings. Virtually there is only a single spar to the lower wings, so that it is more of a 1½-plane than a biplane. The Germans copied this single-spar idea in their Albatros single-seat "chasers" of 1917.

The year 1917 is still too recent for one to give many particulars about the outstanding features of its machines, but one may mention those which are known to be familiar to the enemy, and one may illustrate their outlines to show how they compare with the older types, and thus be enabled to note the line of development.

Here we have the Sopwith "Camel"; the Spad, designed by M. Béchereau, of Deperdussin fame; and the Albatros, D3 type—all obviously descendants of the Nieuport and the Deperdussin and the Tabloid. Also we have the de Havilland 4, built by the Aircraft Manufacturing Company (Ltd.), and designed by Captain de Havilland, as he now is; and we have the S.E.5, built and designed by his successors at the Royal Aircraft Factory, both descendants of the B.E. Then there is the "Bristol Fighter," built by the British and Colonial Aeroplane Company, of Bristol, and designed by Captain Barnwell, a pioneer of flying in Scotland, who built a machine of his own in 1909. It shows traces of the 1910 tractor biplanes.

Finally we have the Gotha Bomber, of evil renown, a descendant of the Caudron and Handley-Page twin-engined machines. Italy has produced the vast three-engined 1,000 h.p. Caproni triplane, but its sheer size prevents it from being illustrated to scale. And so we have in review practically all the salient steps in the development of the aeroplane from its earliest successful effort to its most modern types.

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## *Materials of the Aircraft Industry*

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## *Materials of the Aircraft Industry* IV

THE complex structures known as aeroplanes and airships demand a very wide range of materials for their manufacture. At present, what may be termed organic materials, e.g. wood, flax, etc., are employed in preponderating quantities. Undoubtedly, in the future, however, as aircraft become larger and more standardized, metal construction will be in the ascendant, as is the case in most modern engineering work.

Other materials are on the whole less satisfactory than metal for aircraft building, not being so permanent or so well able to withstand age, varying temperature, and humid conditions; nor can such accurate results be obtained with any other material by preliminary calculation. Again, it is imperative, where feasible, that metal construction should be adopted in order to withstand the wear and tear of commercial service.

This expression of opinion with regard to the prospects of all-metal construction is, it must be admitted, of the nature of intelligent anticipation ; for the number of types of aeroplanes to-day whose principal material of construction is metal can be counted on the fingers of one hand. Nevertheless, metal construction has already been carried out to a considerable extent on airships of the Zeppelin class. The only organic material used on these particular craft is that employed in the manufacture of the envelopes for the gas and for the external covering of the whole machine. These external coverings are necessary to reduce to a minimum the resistance to the passage of the machine through the air. Nothing so light and effective as a textile material has yet been evolved.

Twenty years ago it would have been impossible to build the modern aeroplane as it exists to-day, for the reason that neither the materials nor the machine tools required to work them were then available. Even now, the development of the aeroplane has outstripped the advance in the knowledge of materials and evolution of machine tools. The problem of the aeroplane to-day is largely that of the provision of sufficiently light and powerful engines with suitable propellers. Already aeroplanes are in existence that will climb at an angle closely approaching sixty degrees.

It was not so very long ago that it was proved mathematically to be impossible to construct as big machines as the largest which are in use to-day. The mathematicians were not wrong in their calculations; it was their premises that were incorrect. They assumed that the increase in size and weight of an aeroplane would be in direct proportion to the models then existing. They entirely overlooked the possibility of the improvement of the qualities of the materials used, or the effects of greater efficiency for a given weight in engine design.

The materials of the aircraft industry may be classified as follows: (1) Products of chemical technology; (2) carbon and hydrocarbon compounds; (3) iron and steel; (4) metals (other than iron and steel);

(5) minerals (other than carbon and metals); (6) wood, paper, and their compounds; (7) leather, rubber and moulded compounds; (8) textile material; and (9) miscellaneous material. This is the international decimal classification adopted for the materials of the useful arts, and since it is very useful and logical it may well be employed in the present consideration.

Products of chemical technology comprise inorganic and organic chemicals; explosives; adhesives; glues, sizes; oils, lubricants, fats, greases; paints, pigments, driers; varnishes, "dopes," gums, resins; bleaches, dyes, inks; miscellaneous products. All these are required, to a greater or lesser extent, in aircraft work. Possibly the greatest developments that have taken place in these varied materials are in dopes, glues and lubricants, though all have greatly improved in quality as the result of systematic investigation, careful specification and rigid inspection.

The word "dope" is a common American slang term for a drug or medicinal liquid. In Great Britain it has become a proper noun descriptive of the special coating material applied to the fabrics or coverings of aeroplanes. Dope is not merely required to make an aeroplane fabric weather-proof and air-tight; it must in addition tighten the fabric itself until the latter assumes a drum-like tightness over the spars and ribs of the aeroplane wings, of other parts of the machine. This effect could not possibly be obtained by straining or tightening by hand or even with the aid of wedges and similar contrivances. The crude practical method of finger drumming has now been superseded by the invention of an ingenious little instrument known as a tautometer. This device indicates the deflection at the centre of a given area upon the application of a predetermined pressure. This particular instrument is but one of the many ingenious testing and measuring devices that have been introduced.

It is difficult to combine all the desirable qualities of a good fabric-coating material. It should dry quickly and be very flexible when dry, for, if it cracks or scales, it will not resist moisture. It is of the utmost importance that it should be absolutely impervious to moisture. It must also withstand general wear and tear, vibration, extremes of heat and cold, the effects of sunshine and of frost. Neither expansion nor contraction should disturb it. It should be flame proof when dry, and should be unaffected by lubricating oil or petrol dropped from the engine. It must be light and have good adhesive properties. It should also be non-poisonous. Dope is usually composed of cellulose acetate, triphenyl phosphate, acetone (or acetone substitutes—e.g. some of the ketones), alcohol, benzol, etc. Plasticizing materials, waterproofing and fire-proofing agents are added as necessary.

Dope film being porous to water vapour, must be protected by the application of waterproof varnishes. Protracted experiment at the Royal Aircraft Factory has led to the conclusion that the deterioration of the varnished and doped surface of an aeroplane wing is partly due to the actinic rays of the sun. The remedy, therefore, is to admix suitable anti-actinic pigments with the coating material, and to avoid the use of drying oils in contact with the fabric.

As has already been mentioned, great improvements have been made in glues, and much has been discovered in reference to the best methods of application. In pre-war days glue was treated rather as an unconsidered trifle in furniture making and repairing or for the handyman's workshop. Now, however, as the result of bacteriological and chemical research, accompanied by protracted mechanical tests, it has been withdrawn from the abyss of uncertainty to the position of a substance whose qualities can be definitely specified. This knowledge will be of great value to all the wood-working industries. Glues are now obtainable which are stronger than the wooden parts they are intended to hold together. That is to say, a properly made modern glued joint will only give way by the shearing of the wood itself, and not by parting at the joint. A good deal of investigation is still necessary, especially as regards the most suitable forms of glue and cement and their application to ply-wood manufacture. The official specifications for glues might also be overhauled with advantage.

As regards lubricants, marked advance has been made in the treatment of castor oils. As castor oil does not mix with petrol, its use is imperative in rotary or other engines, where the combustible mixture is drawn from the engine-crank case chamber. The constitution of a good castor lubricating oil is very similar to that of the medicine.

A great deal has been done in engine design to reduce the working temperature of the lubricating oils. A comparatively low working temperature is essential, or else the oil film in the bearing becomes too thin to be effective. This temperature should not exceed 66 deg. C. (or 150 deg. Fah.) and can only be assured on what is called the dry sump system, where all the oil not actually being pumped under pressure around the engine bearing is pumped out of the crank-case sump into a storage and cooling tank (open to the atmosphere).

Carbon and hydrocarbon compounds form the mediums for working up the final aircraft materials, rather than actually being incorporated themselves. They comprise peat, coke, charcoal, cannel coal, bituminous shale, coals, anthracite and graphite coals, graphite, plumbago, carbon, bitumens, asphaltum, mineral pitch, waxes, and petroleum.

A most important compound is calcium carbide, which, as is well known, produces acetylene gas when brought into contact with water.

Acetylene welding has been brought to a high stage of perfection, and it is wonderful what neat welding is accomplished with its aid nowadays, on delicate aeroplane parts, by women welders. The Germans have brought this form of welding to a very advanced state, as is evidenced by petrol tank seams and other work observed on Zeppelins that have been brought down in this country.

The increased employment of electrical devices on aircraft now means a very considerable output of carbons for the brushes of magnetos and small dynamos, while the bitumen and asphaltum products—often in conjunction with india-rubber—provide electrical insulation.

Iron and steel, as was suggested in the opening paragraphs of these notes, large as their use is to-day, are destined to play an even more and more important part in aircraft construction as time goes on.

This group is generally classified into pig iron, cast iron, malleable cast iron, wrought iron, ferro-manganese, ferro-silicon, spiegeleisen, and steel.

The subdivisions of steel are becoming very numerous indeed, as the result of patient research. However, Colonel Bagnall Wild, the popular head of the Aviation Inspection Department, recently stated that five forms of steel would cover 80 per cent of the tonnage for aircraft work. These five varieties are known to the trade as 0·15 per cent case hardening, 0·3 per cent case hardening, 0·4 per cent case hardening, 0·3 per cent nickel steel, and 0·3 per cent nickel chrome steel. The last-named is very similar in composition to the much-advertised stainless table knives that are so popular to-day on account of their labour-saving qualities. A development of the application of the so-called stainless steels is in the manufacture of rust-proof ball-bearings. This is a very important use, for when a ball bearing fails for any other reason than sheer overloading, it is usually found to be due to the deterioration of the balls as a result of the formation of rust. Ball bearings are used to a very considerable extent on aero engines and for control pulleys on aeroplanes.

An important factor in the use of steels is their proper heat treatment, after being worked into any required shape. Crudely speaking, what is meant by the heat treatment of steel is to raise its temperature to a certain point (often to a cherry-red colour) and then suddenly reduce its temperature by immersion in a bath of liquid at a much lower degree of temperature. This work requires considerable skill, aided by suitable heating furnaces and quenching baths. The latter are variously composed, and many consist of oils, or of more or less secret mixtures of certain salts in water.

One heat-treatment process has been so developed that it can be placed in comparatively unskilled hands. The results obtained by this method are more certain than those obtained by other processes by the most highly skilled workman. It consists of an electric furnace, in which the steel to be treated is immersed in a molten salt bath. When the correct temperature has been reached an indication is given on an electric galvanometer; at this juncture the piece is immediately removed and quenched in a hot bath. Incidentally, since the process is carried out in molten salt baths, there is no scaling due to oxidisation and no warping of the steel object. As the principle of the operation of the system is founded on the recalescence point of the steel, and its varying magnetic properties at different temperatures, it can only be employed for carbon steels. That is, for such steels as are used in the manufacture of gauges, rifle barrels, and the like.

The practical result of the heat treatment of steel is that the strength for a given weight is much greater. Lightness being of all importance in aeroplane construction, heat-treated steels are obviously essential, notwithstanding their greater cost. An objection to heat-treated steel is that no alterations can be made to a fitting when in its place, for any attempt at hammering or bending will destroy its qualities.

Ailerons—or, as they are sometimes loosely termed, balancing flaps, on account of their function on the crosswise balance of ana eroplane—are often made on steel frames. If not wholly so made, the trailing edges are usually of oval steel tubing. A steel-framed aileron can be made lighter and stronger than a wooden one. All-steel wings have been made that are as light and strong as wooden ones, but they are not yet a commercial article like the ailerons. This is due to manufacturing difficulties. The slightest crinkle or dent in any part of the special thin sheet steel used for this work is a source of possible breakdown. Hence, while the wings can be constructed satisfactorily under experimental conditions, directly the manufacturing stage is reached there is too much waste of material. However, this matter largely rests upon the evolution of suitable tools for corrugating and shaping the steel sheets without damaging them in any way. As aircraft become bigger, thicker steel sheets can be employed, which will facilitate manufacture.

The whole question of steels, as applied to aircraft manufacture, is a very interesting one, upon which volumes might be written even on the knowledge that is available to-day. The modern aero engine would have been an utter impossibility without suitable steels.

Metals other than iron and steel—or, as they are sometimes described, non-ferrous metals—are extensively employed in aircraft construction, generally in the form of alloys, a most important class being the aluminium alloys. Aluminium has always been very attractive to aircraft designers on account of its comparative lightness. Its softness and weakness, however, put it out of court for use in the pure state. Alloys of which aluminium forms the base variously contain either copper, nickel, magnesium, antimony, tungsten, tin, zinc, etc., or more than one of these metals in proportions that vary from 2 to 10 per cent. As an example, wolframinium, an alloy that has been utilized in the construction of Zeppelins, contains approximately 98 per cent of aluminium, 1·4 per cent of antimony, 0·4 per cent of copper, 0·04 per cent of tungsten, and 0·015 per cent of tin. Its density is very close to that of pure aluminium (about two and a half times that of pure water).

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Perhaps the best known British aluminium alloy is Duralumin. It has certainly proved very successful, and is therefore difficult to obtain, the demand being so great.

Aluminium alloys, like steels, have been employed in the construction of both the wings and ailerons of aeroplanes. The same manufacturing troubles arise as occur in the case of steel, though not so markedly, on account of the greater ductility of the aluminium alloys. Innumerable fittings and parts of aircraft are constructed of aluminium alloys, and they are found to be very satisfactory. The only exception is in the case of seaplanes, where they should be avoided on account of the deleterious action of salt water. Even the rare metals, such as iridium, platinum, etc., find a place on aircraft in the form of parts of aircraft instruments. It will be fully appreciated therefore that the range of metals demanded for aircraft building is a very wide one indeed.

Prices of all metals are very high nowadays, as is only too well known to those conversant with the metal markets ; copper is about £110 per ton (say, 11¾d. per lb.), while tin is nearly £300 per ton (say, 2s. 8d. per lb.). And this, be it noted, is for the raw material before any work is put into it.

The minerals, other than carbon or metals, are only indirectly used to any extent in aircraft work, and therefore need not be considered in detail at this point.

Strictly speaking, wood is not a material but a structure. It is essentially composed of a stuff, allied to cellulose, that may be termed wood substance. To the aeroplane designer who is also an idealist there is only one wood, and that is time-seasoned silver spruce from British Columbia. Unfortunately to-day, as regards timber, and possibly many other things, time has to be taken by the forelock. The timber-drying kiln has to supplement, to a considerable extent, nature's somewhat tardy, even if sure, methods of seasoning wood. Further, by reason of the fact that silver spruce is not one of the common woods of this country, it is not so easily obtainable as certain others. On the whole the aeroplane manufacturer's interests are opposed to the designer's. A good word was said, earlier in these notes, as regards the progress of the development of glue. Glue has not, however, quite reached that stage when it can be universally employed in the building up of such important parts as spars, etc., thus displacing the laborious shaping of these parts out of selected and valuable lengths of straight-grained, knotless wood. Out of such a prime cut of solid wood, something like 30 per cent is frittered away in shavings and chips, and it would be no unimportant economy if spars, and similar parts, could be built up out of a number of smaller pieces. Already a very considerable quantity of ply-wood is in use. Some of this ply-wood is so well made that it is often employed in modern aeroplanes for use in parts under stress, in place of wiring. Ply-wood consists of three or more layers of thin wood, which are glued together so that the grain of the outer plies runs lengthwise and of the central ply at right angles to the length. By aid of the circular cut, sheets of material, larger and much wider than the original tree, can be obtained.

As in the case of metal working, absolute accuracy in wood working is not only impossible, but also unnecessary. Hence maximum limits are required for all dimensions in aeroplane work. These limits are naturally much wider than those for metal work, and are of the order of one-hundredth of an inch for holes; or three-hundredths of an inch for lengths up to three feet. Where the design of the wood part is such that there is a tendency to warp across the grain, the limits should be increased to five-hundredths of an inch, to provide for atmospheric effects. When seasoned wood has been milled and laid aside for ten days or so, it can be drilled by jig with safety and accuracy, before the metal fittings are assembled, as under these conditions there is no appreciable shrinkage. One very important result of the manufacture of aeroplanes in very large quantities has been the adaptation of manufacturing processes closely allied to metal-working practice—viz. the extended adoption of suitable jigs. A jig is a device which holds the material that has to be shaped and at the same time provides a guide for the cutting tools. Thus large numbers of identical parts can be made with comparatively unskilled labour. Other jigs are employed to accelerate the assembling of the machine parts—on the principle of a place for everything and everything in its place. An intelligent and extended use of jigs reduces the time taken to make an aeroplane by over 50 per cent.

Careful testing of woods and scientific cutting up of baulks of timber have resulted in the possibility of using many kinds of wood which were at one time considered worthless. Still more could be done if this country had a well equipped and staffed Forestry Department, as is the case in India, Germany, and the United States of America.

Leather, rubber, and moulded compounds find their appointed place in aircraft construction. Leather is chiefly employed for upholstery, pilots' quick release belts and straps, and for protection of parts of the fabric on the fuselage, etc., that are likely to get chafed by the control wires. Rubber is the supreme material as regards the springing of under-carriages. Many metal springing arrangements have been experimentally tried, together with, or without, hydraulic buffers, but there is nothing that comes up to rubber. The Germans have found this out to their cost, since they are very short of this particular material.

Textile materials, so far, are exclusively employed for covering the wings of aeroplanes, though suggestions have been made that vulcanized fibre, ebonite, celluloid, or aluminium sheets might be utilized with advantage. The material for the fabric is now chiefly unbleached linen, but cotton, calico, ramie cloth, and silk are sometimes employed. In German practice a mercerized cotton is often used on the under-surface of a plane and quite a rough canvas-like material on the top side. This is a very economical practice, for the efficiency is not impaired, since, as there is, what might be popularly termed, a partial vacuum on the upper side of a wing, there is no question as to increase of resistance. Cotton fabric is often used by the Allies for school machines, on account of its cheaper price. The great difficulty with this material is the large quantity of fluffy hairs on its surface, greater weight, and its undue absorption of dope. The hairy surface prevents the proper application of the dope; and also tends to cause minute air bubbles to form in the latter. Air bubbles in dope cause the film to break up locally, and then the planes become soggy. To remove these fluffy hairs as much as possible, the cotton is either singed or chemically scoured. Linen fabric weighs about 4 oz. per yard as against 3¼ oz. for cotton fabric. The linen is 50 per cent stronger than the cotton.

CALIFORNIA

*The British Aircraft Industry*

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# *The Aerial Engine*

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## *The Aerial Engine* V

AT the present time when considering the aerial engine we need deal only with the reciprocating internal combustion type ; and without venturing to prophesy too much this will probably be the case for at least the next five to seven years. The steam engine, the electrical motor, and the internal combustion turbine engine, in their present state of development are such that we can undoubtedly rule them out of court. Anyone, therefore, who contemplates the situation as to manufacturing, designing, or buying an aerial engine is limited to the possibilities of the internal combustion engine.

In addition to the point of view already advanced, the engine has to be considered in relation to the machine in which it is to be installed. Here, again, we have distinct limitations in the type of machine—viz. the Dirigible Airship, the Seaplane, and the Aeroplane; and, on the ground of weight, having to be as low as possible and size having to be as small as possible we are again limited to internal combustion.

It may be well to state, at this stage, what changes are likely to occur in the near future, for these possible changes are, in the opinion of the writer, really very small. The chief direction in which there is likely to be an alteration is in the matter of fuel. Petrol has held the field, principally by reason of its abundance and its consequent cheapness. Immediately before the outbreak of war benzol threatened to become an active competitor, especially as its properties were such that it could be used alternately with petrol in all makes of engines then existing. Now another possible fuel is alcohol, which has been investigated very thoroughly in Australia and America, and has been widely used in Germany. It has been found that the root principle of design and construction of an engine for use with this fuel need differ little from that of an internal combustion engine using petrol.

Perhaps the biggest change will be in the direction of the use of the two-stroke engine, which will find its place alongside its older brother the four-stroke engine. Most people know something about the four-stoke motor on account of its presence in motor-cars ; they know that in each cylinder four strokes of the piston are necessary for obtaining one explosion or power stroke. It is from this fact that the internal combustion engine employed on motor-cars and aircraft received the name of the four-stroke engine. It is possible, however, to construct engines so that one power stroke is obtained for each set of two strokes performed by the piston, and not only is this possible, but it has become a practical proposition. The earliest form of two-stroke engine was charming in its simplicity, but very uneconomical. In the attainment of economy much of the simplicity has been lost ; nevertheless, in its perfected form the two-stroke engine compares favourably with the four-stroke engine in this respect. From the point of view of the manufacturer this possible change will in time make no differences in the arrangement of workshop, or workshop processes, or plant, other than are demanded by the usual advances in design of any form of prime-mover; and as far as aircraft manufacturers are concerned it will be found that the housing of the engine is identical.

Considering for the moment only the four-stroke engine, it is as well to note in passing that the gases in the cylinder can act in the way familiar in motor-car engines and also in an alternative case in a manner similar to that existing in engines of the Diesel type. Technically these two forms are known as the constant-volume and the constant-pressure cycles of operation. The present trend of invention and design does not lead one to suppose that the Diesel principle will come into vogue, although not a few large firms are experimenting along this line.

In a paper read before the Institution of Automobile Engineers, Mr. A. G. Clark sets out the main features desirable in an aerial engine, which he states to be as follows: (1) Reliability, (2) High power for given weight, (3) Economy in fuel and oil, (4) Low air resistance, (5) Controllability, (6) Freedom from vibration, (7) Accessibility, (8) Silence, (9) Cleanliness, and it would appear that our present war experience not only corroborates this list of requirements, but also in a great measure points to the correctness of the order of importance of these requirements. Present-day engines can be divided into classes under two schemes: (1) In reference to the arrangement of cylinders. (2) In reference to the method of cooling. Because a fair proportion of the heat of combustion is radiated to the cylinder walls it is necessary to provide some means for absorbing the heat so that there is not undue heating of the cylinder. Water or air is used for taking up this waste heat and the engine is classified correspondingly as water-cooled or air-cooled. In water-cooled engines, the water circulates in a jacket round the cylinders and, after taking up heat, passes to a radiator where the heat is given up to the surrounding air, leaving the water at a low temperature so that it may pass again to the cylinder jacket in a closed circuit. In air-cooled engines the heat is given direct to air and not to an intermediate medium, while the cylinder is itself provided with fins, whereby a greater radiating surface is exposed to the air. There are no air-cooled engines over 150 h.p., and water cooling is used with engines from 80 h.p. upward; there is thus a certain amount of overlapping of the range of horse-power when air or water cooling is adopted. Above the 150 h.p. stated as the upper limit, it is impossible to keep the engine sufficiently cool by air cooling, and in the common range the question resolves itself into an investigation of the ultimate use of the engine. An air-cooled engine is lighter, but has a fuel and oil consumption per hour greater, than a water-cooled engine of the same horse-power. If the engine is employed for short periods only, then the difference in the total fuel and oil consumption is less than the difference in the weight of the engine sets, and the air-cooled set scores, but for long runs the advantage falls to the water-cooled engine.

The division into types and sub-types in accordance with the arrangement of cylinders can be made as follows: (1) Rotary engines—(a) Radial, with fixed crankshaft; (b) Radial, with oppositely rotating crankshaft. (2) Stationary engines—(a) Vertical; (b) Vee; (c) Arrow; (d) Radial; (e) Horizontal opposed; (f) Cross.

Type 1 (a): Rotary radial engines. Examples of this type are the Gnôme, Le Rhône, and Clerget, in which the cylinders are in one plane radiating starwise, with the connecting rods all acting on one fixed crank arm. In one variation forming type 1 (b) the cylinders rotate and the crankshaft is mounted so as to rotate in the opposite direction. The balance in rotary engines with seven or nine cylinders is practically perfect, but the trouble with them is that a fairly large surface is presented to the wind, and they do not lend themselves readily to installation inside the streamline form of fuselage. This defect is to be noted in addition to the limitations recorded for air-cooled engines, as it is practically universal to construct rotary-radial engines for air cooling.

Type 2 (a): The vertical engine. Examples of this kind are the Beardmore and Green, in which the cylinders are set in one plane, one behind the other, like the Rolls-Royce and Napier car engines, with the connecting rods each acting on its own crankpin. This type is well balanced and presents a narrow entry into the wind. With the more usual arrangement of the valves overhead on the top of the cylinder this engine is somewhat tall, and with the six-throw crankshaft is inclined to be over-long.

Type 2 (b): The Vee engine. Examples, not by any means a complete list, are the Wolseley, Renault, Sunbeam, and Curtiss, in which the separate cylinders of a vertical engine are replaced by pairs of cylinders at an angle to each other arranged in parallel planes transverse to the axis of the crankshaft. When eight cylinders are used they are arranged in four sets, the pairs being at an angle of ninety degrees, and when twelve cylinders are employed the six sets are pairs at sixty degrees. In either case the result is a very smooth-running engine, and a compact one. The eight-cylinder engine is inclined to present a wide front, owing to the larger angle of ninety degrees being necessary.

Type 2 (c): The arrow engine. This is really a combination of types 2 (a) and 2 (b), for it comprises sets of threes, so that the complete engine has a row of vertical cylinders and two rows of inclined cylinders. The chief exponent of this construction is the Sunbeam Company, with an eighteen-cylinder engine. The reason for this multiplying of cylinders is in the main due to the physical limitation of the maximum diameter of cylinder possible. It therefore results that increased powers can be obtained only by multiplying the number of cylinders. The engine is very compact, and because of the greater frequency of the application of power impulses to the crankshaft, a very steady drive is obtained.

Type 2 (d): The stationary radial engine. There are but two active makers of this type, the Salmson and Anzani. The cylinders are in one plane, with rods acting on a single crank arm.

Types 2 (e) and 2 (f) are really special cases of the last-mentioned type, and do not figure among the live examples. For special purposes each has a certain limited field, but it can be taken that for all practical purposes types 2 (a), (b), (c) meet general requirements.

There are several important points which manufacturers should bear in mind, and these have now to be considered. Engine vibration must be reduced to a minimum for two reasons, one being the desirability of having as small engine bearers as possible, on the ground of weight consideration ; and the other the general necessity for avoiding the setting up of vibration sympathetically in other parts such as the interplane wires of the aircraft. This feature of sympathetic vibration can be readily visualized if one recalls, as an example, how by timing the push on a child's swing a big motion can be obtained with relatively little effort, i.e. the movements of the person pushing must be in sympathy with or synchronous with those of the swing.

As an aeroplane or airship ascends it passes through air which gets less and less dense, and the power obtained from the engine as measured under ordinary conditions also diminishes. The lost power may be regained in part by certain expedients such as using an adjustable carburettor; forming the combustion chambers with adjustment, as on some motor bicycles, whereby the compression can be varied; or by using forced induction, that is positively pushing the gaseous mixture into the cylinder instead of relying upon the difference of pressure in the inlet pipes and the pressure of the atmosphere.

In pointing out the desirability of progress along this line it is not forgotten that a good deal of research and practical trial has been done already—in fact so much that little remains to be learnt as to the conditions involved. Nevertheless the means adopted to put the knowledge gained to practical benefit still leaves room for valuable improvement.

It is known to most of us that a period of stagnation in the designing of motor-car engines occurred in the years 1910–1914. In 1914 America especially broke away in the direction of experimental use of new materials. Aluminium, hitherto used only for the crankcase, was used for cylinders and pistons. Bronze was used for valve guides and valve seats in overhead valve constructions. Connecting rods were made of extra special steel, and in general the then prevailing practice in materials was thrown overboard. As the metallurgist makes further advances designs will need corresponding amendment. What effect this will have in the near future in changing the type of engine from that now employed it is difficult to predict.

It may be thought that too much stress has been laid upon the smallness of possible changes in engines in the near future. The writer has had in mind the desire of manufacturers not only to gauge the possible quantity of business, but also the eventuality that some manufacturer or other will by a marked change of an advantageous kind either corner the market or force competitors to pay royalties on patented matters of an essential character.

As appears from other sections of this issue, the engine manufacturer can look for a market for his product in sundry directions. These may actually be greater in number than predicted, but will certainly not be less; the more modest forecast should, however, be taken when weighing up prospects. Engines for airships and large-capacity aeroplanes will be of horse-powers exceeding 300 and as much as 800–1,000 h.p. per engine. Judging by the researches and experiments already made on the physical limitation of cylinder sizes, it would appear that current practice of multiplying the number of cylinders in order to obtain increased horse-power per engine is the only possible one. Broadly viewed the possibilities here lie mainly with the military requirements. A large number of passenger-carrying machines will be built, but it does not appear that the future of commercial aerial transport—i.e. cargo-carrying aeroplanes—is assured, for on grounds of expense such transport as is done will probably be of a subsidized nature, such as postal transport, and bound or linked up with military requirements. This may appear to be a cautious view, but it is as well to record it as a considered judgment. The view taken may be wrong, if so it errs on the right side.

The engines for smaller aeroplanes will be of the 80 to 300 h.p. range, and these will fall into two types, the rotary radial air-cooled engine and a six-cylinder (three-cylinder if two-stroke) vertical water-cooled engine. The field is immense, the demand from military and civil sources being not only large but constantly increasing. If one reviews the progress of motor-car engineering during the period 1904–1914 one will not be very far out in assuming a similar state of affairs for the aerial engine industry for the ten years following the war.

Having in mind the necessity of Britain's possessing absolute supremacy in the air, it can be asserted confidently that the aerial engine industry will constantly expand, and that the manufacturers engaged therein will be handling live and sound business propositions as well as having the proud knowledge that they are in no small measure contributory factors in the maintenance of our international welfare.

# *The Propeller*

## *The Propeller* *VI*

THE propeller, or airscrew, as it is officially called, converts the rotational energy of the engine (apart from necessary losses) into the " pull " or " thrust " energy which drives the aeroplane. The " pull " or " thrust," according to whether the machine is a " tractor " or " pusher," is taken on the blades of the propeller and transmitted to the engine or propeller shaft, and thus through the engine casing on to the machine.

Propellers are usually made of walnut or mahogany. The main conditions to be satisfied are that the wood shall have sufficient strength, be free from serious defects, and obtainable in sufficient quantities. It is delivered in planks, varying in thickness from ¾ in. to 1½ in. Although the seasoning process has recently had to be carried on in the main by artificial means, the odium incurred in some quarters by certain processes of " kiln drying " has been to a large extent removed.

The planks are planed down to the thickness shown on the working drawing, and after being marked are cut out by a band saw. They then stand for some time in the same temperature as that of the gluing room, an operation needing much care and attention to specified temperature conditions.

The number of laminations or thicknesses of board used in a propeller varies from five to ten, according to the thickness of the wood available and the size of the propeller. After the gluing is done the block stands a few days and is then rough shaped. It then stands a few more days in order to recover from strains, and is finally shaped to the required sizes. The finished propeller must be perfectly balanced about its centre. The balance is obtained, in the first instance, by putting the heavy end of one lamination against the light end of the succeeding one and so on, and in the final shaping by leaving a small allowance all round, which can afterwards be taken off the heavier side. The propeller is then either polished or varnished, or the blades may be covered with fabric and enamelled or painted. The fabric acts as a preservative and prevents splintering.

In the design of a propeller the important points are that the blades should have a maximum aerodynamic efficiency, and sufficient strength to withstand the thrust which they transmit to the shaft and the centrifugal force of their rotation. The latter forces are very high, amounting on an average propeller to several tons on the root of each blade, and the small amount of comparatively thin brass sheet used in seaplane propellers adds very substantially to this force. In order that the most useful parts of the blades, near the tip, should have as high an efficiency as possible, the section there is made as thin as the strength of the material will allow, the thickness gradually increasing in order to take up the centrifugal and bending stresses.

The efficiency of a propeller depends, to a large extent, on the shape of the cross-section of the blade. The best shapes of aerofoil for cross-sections are usually determined by laboratory experiments. The term "efficiency" means the "thrust" or "pull" horse-power given out by the propeller, divided by the total power put into it through the propeller shaft. Efficiency varies greatly with the conditions of machine speed and rotational speed; in favourable conditions at top speed 75 per cent of the actual propeller shaft power is absorbed usefully, the other 25 per cent being lost in the kinetic energy of the slipstream. The lost energy of motion in the slipstream consists of the straight back draught, a general rotation of the whole of the stream, and to a very small extent of swirls or eddies.

In the cases of both slow and fast machines, the engine rotates at the same rate in order to develop its full power; consequently, the advance per revolution is more with the fast machine than with the slow, and the blades need to be set at bigger angles for the fast machine. Now, if the same blades were merely increased in angle, the engine would be unable to turn the propeller up to its full speed, so that, in order to compensate for the increased angles, the surface needs to be made less. The need, then, is for a large low "pitched" propeller for a fast machine. If a low-pitched propeller is put in a fast machine, at top speed the engine races away beyond its permissible limits and probably breaks down.

# *The Fuel Supply*

IT may be taken for granted that, until the war ends at all events, all planning of aeroplanes will proceed on the supposition that petrol is the only fuel worth consideration. New discoveries and experiments may, and very likely will, produce alternative fuels; but these are matters to be considered after the war. The engines of existing aeroplanes have been designed with a view to the consumption of high-grade petrol; and a radical departure from present practice could only be made as the result of exhaustive experiments on some other fuel.

At the moment more vital problems confront the designers and manufacturers; and, further, were an alternative fuel, with a new design of engine, found to answer well, there would be the colossal problem of building up the production of such a fuel in the necessary quantities and of uniform quality, and transporting it to the various fighting fronts under suitable conditions. Granting that such a fuel may exist, its manufacture, transport, and distribution would offer difficulties in war time wellnigh impossible to overcome. For practical purposes, however, such an alternative fuel has not yet been found.

In the early days of the war, when Germany was hard put to it to find petrol for her land transport and her air forces, substitutes and combinations were tried by her with no great success. It will be remembered that the British blockade had isolated Germany from her largest source of petrol—the United States—and that Russian supplies had *ipso facto* been cut off by the war, whilst at the same time Rumania, though a neutral, had placed an embargo on the export of petrol. This left Germany with only the Austrian oil-fields to depend on, with the addition of a small quantity got from a few oil-wells on German territory. Germany was then at starvation point for motor spirit, and was forced against her will to use substitutes. We know that substitutes were tried on aircraft, and one of the indirect ways in which we got to know it is as follows:

A German scientist, Dr. Karl Dieterich-Helfenberg, seized the opportunity offered by the necessity for analysing such substitutes by way of safeguard to invent a portable testing apparatus for users of light motor fuels. It is so simple that anyone can use it, and by heating a small quantity of the liquid and marking on a prepared card the temperatures at which fractions of it evaporate a curve is plotted which, with the other data obtained, shows pretty clearly the composition of the fuel. On more than one occasion the inventor gave addresses, in which he showed how to operate his tester. In recommending it, he publicly stated that it had been used and approved in the Zeppelin factory at Friedrichshafen and by the Air Services on the various fronts. Now, the only use for such an apparatus is to discover the exact properties of a composite or substitute fuel; it would be superfluous with a "straight," pure fuel like high-grade petrol, the composition and curve of which are known. The statement of the German scientist, placed alongside what we know of Germany's terrible straits for petrol until the Rumanian oil-fields were occupied, shows with practical certainty that the enemy was driven to use substitutes even for his aircraft.

Data are lacking to show whether, and if so to what extent, the immense extension and advance of German aviation were associated with a return to the use of what may be called normal fuel for this purpose. From what one learns here and there some of the German substitutes were excellent taken individually; but the lack of uniform quality, the variations in blending, and the uncertainty from one day to the next as to what fuel an engine was expected to run on, must have been serious drawbacks and have tended to disquiet the aviators who had to use these fuels. The enemy is now provided with good fuel for his air services.

It is an axiom that petrol, if it is to be used without mishap in aeroplanes, must be of the highest quality. It must also be perfectly pure. A spirit fulfilling these requirements can be got in several parts of the world under Allied dominion, but our two chief sources of supply are the Dutch East Indies and the United States of America. Persia as a potential source possesses enormous capacity, but its development has been hindered by obstacles familiar to us all—the difficulties which the war has placed in the way of the manufacture and delivery of plant.

An abundant supply of crude oil suitable for refining for aeroplane petrol is assured in the Dutch East Indies. There need be no fear that this source will fail, for the next few years at all events. But petrol on the spot in (say) Sumatra, and petrol on the front in (say) France, represent two quite dissimilar propositions. There is, to begin with, the long sea voyage from the Dutch East Indies, and the equally long return trip. Not only have vessels on this route to pass through the Mediterranean (even if they unload at a Mediterranean port and do not proceed to Great Britain), but the allocation of tankers for these long voyages is uneconomical compared with the quicker transatlantic trade.

Good spirit for aeroplane purposes comes also from the other side of the Atlantic. As regards its principal source, the United States, some anxiety was expressed a few months ago as to the country's ability to turn out enough for the Allies' requirements. That anxiety is now allayed. A recent statement by the Petroleum War Service Committee puts the matter beyond all doubt; and as it has already been published in the United States there can be no harm in paraphrasing a sentence or two from it. There is no shortage, we are told, of petrol for use in the States, and while there is an increasing demand abroad for the Allies' needs, the chief limiting factor is shipping tonnage. All the petrol is being forwarded for which ships are available; and America can and will supply the increased war demands, provided sufficient tank steamers can be obtained. Of course, these remarks apply to petrol as a whole; but they are true in particular of the higher grades used for aeroplanes.

It is of urgent importance to develop our home supplies of mineral oil so that the demand on tonnage may be less severe. We have a certain source of this in the cannel and certain other coals of Great Britain; some would claim the same for our unworked shale deposits and for peat. Even if the motor spirit thus obtained were not of the superfine grade required for aviation purposes, it could substitute high-grade spirit or help to release tonnage. The question of home sources of oil supply is too large for discussion here; but it may be remembered that any practical step taken to develop domestic supplies would be of real help in the problem of aviation fuel.

*The British Aircraft Industry*

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## *Instruments used in Flying*

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## *Instruments used in Flying* VIII

LIKE the steamship or the motor-car, the aeroplane is provided with a number of instruments or accessories which, though not essential parts of its structure, are yet practically indispensable for its operation. These include besides oil gauge and compass, indicators of horizontal level, of height in the air, and engine speed and air speed. There may also be apparatus for sending wireless messages, appliances for photography, and bomb-sighting and bomb-releasing mechanisms.

The accessory instruments are so arranged that the pilot can readily see and reach them, and means must be provided for illuminating them at night. For this latter purpose shielded electric lamps are employed, but the problem involved is not so simple as might appear at first sight. While sufficient to show up the dials and indicating hands of the various instruments, the illumination must be subdued, for the pilot on turning his eyes from a brightly lighted instrument board would be able to discern nothing in the darkness of the night, whether an enemy machine or his own landing ground. Some help is obtained in this respect by making the dials of the instruments dead black, with white figures and hands.

Seated in his cockpit or " office," the pilot has in front of him a dashboard on which the various accessories are mounted. At the top left-hand corner there may be a switch-board from which the electric lamps are controlled. The compass may occupy the centre of the upper section, with the engine-speed indicator, or " rev." counter, to the left of it and the height indicator, or altimeter, to the right, the air-speed indicator finding its place below the latter. The horizontal level is mounted in the centre of the lower section, flanked on one side by the air-pressure cock controlling the petrol supply, and on the other by the main switch for the engine ignition. The petrol gauge is to the right. The top of the " joy stick," or control lever, carries an engine cut-out switch worked by the finger.

The construction of an aeroplane compass is a very complicated matter. The usual corrections required in the case of a ship's compass have to be applied, and in addition special precautions are needed to counteract the effects of vibration and the swinging of the needle when the machine is banking. The indications of the compass are so arranged that the pilot may conveniently read them in a vertical plane instead of in an horizontal one, as with a nautical compass. The card has an annular flange, on the periphery of which the cardinal and intermediate points are marked in reverse direction. Supposing that an aeroplane were travelling due east and the pilot were looking down upon an horizontal compass card in the direction of his travel, then, with the ordinary marking, the east point would be farthest from him and the west nearest; but by the expedient of reversing this order of marking the true direction is revealed to him as he views the rear edge of the card.

The purpose of the transverse level indicator or inclinometer is to show whether or not the aeroplane is on a level keel. It is in fact a spirit level, but the tube in which the bubble moves is arched instead of being straight.

The height indicator is an aneroid barometer, the dial of which is graduated not in inches but in feet above the sea-level or other datum. Here again a great deal of work has been required to produce an instrument that will meet the special conditions required in an aeroplane—to get, for instance, a needle that is steady and non-vibrating without destroying the accuracy and quickness of the indications.

Worked off the main shaft of the engine, the revolution indicator consists of a dial four or five inches in diameter, with white figures and hand. One representative type is marked from 6 to 26 in intervals of 2—i.e. 6, 8, 10, etc. The intervening spaces are graduated in ten minor divisions, with a larger mark halfway to show 7, 9, 11, etc. Each figure represents hundreds of revolutions per minute, and the minor divisions thus enable the instrument to register a difference of twenty revolutions per minute. The motion is transmitted from the engine by a flexible shaft, and, as with the speedometer of a motor-car, actuates the indicating pointer electrically or through a device like a centrifugal governor. Here again vibration is a factor of which careful account must be taken in the design, and a very considerable degree of accuracy in the indications is essential if the instrument is to serve its purpose of providing the pilot with a check on the performance of his engine.

The air-speed indicator, the function of which is to show the speed at which the aeroplane is flying through the air, depends on the use of Pitôt tubes. The attainment of accurate results is not an easy task, and in the past there has been a good deal of controversy about the precise methods to be used in controlling the action of the apparatus.

It is obviously necessary that the pilot should know the exact quantity of petrol he has available, for unless he has that knowledge he may find himself without a sufficient supply with which to get home and may be obliged to make a forced landing, possibly within the enemy's lines. Gauges are therefore fitted to inform him of the state of his main pressure petrol tank and also of his emergency gravity-feed tank. He further requires a pressure gauge to inform him that the necessary pressure is being maintained. Here again the need for accuracy entails many difficulties, such as on the one hand the transmission of the indications to a point where they can be conveniently seen, and on the other the avoidance of disturbing effects caused by the different motions of the aeroplane. Pressure gauges for the lubricating oil of the engine are also necessary. The lubricating system is a vital part of a modern air engine, and the pilot cannot afford to be ignorant whether or not it is working properly.

# *The Commercial Potentialities of Flying*

## *The Commercial Potentialities of Flying* IX

THE results of recent developments in the direction of mechanical flight will certainly make themselves felt in the world within a very few years after the declaration of peace. Commercial men cannot afford to neglect any new and time-saving means of transit, and an investigation of the business value of high-speed travel, together with a review of its application to mails and passengers, may be of interest, especially since the subject has hitherto been little explored.

The modern express train, carrying out journeys up to 150 or 250 miles, is unlikely to be supplanted by the flying machine, for the following reason : The big stations of all important railways are invariably near the centre of cities and within easy access of all other parts ; it, therefore, takes the business man but very little time to get from his office to the train. On the other hand, aerodromes, covering perhaps fifty or more acres, must necessarily be several miles outside a city. It, therefore, would take half an hour or more to reach the aerodrome.

It follows that, although the speed of the flying machine may be 100 per cent greater than the speed of the train, there will always be time lost in getting to and from the aerodrome. It is only when distances of not less than say 250 miles are under consideration that the flying machine is likely to supersede the express train.

The flying machine has another competitor—the passenger and mail steamer. In point of speed this is not nearly such a formidable rival as the train, the speed of the flying machine being six or even eight times the speed of the average passenger steamer.

The greatest saving in time, and consequently in money, can therefore be expected on long-distance journeys, more particularly in the case of oversea routes.

Flying machines, that is to say heavier-than-air flying machines, can be classified under two heads: those which fly overland, and those which fly over the sea.

The establishment of flying services throughout the world will necessitate a very complete organization of landing points, fuel depots and repair stations. These can be located at short and convenient intervals on *terra firma* or at sea, and the selection of them will present but little difficulty.

With the growth of steam navigation throughout the world during the last sixty years, coaling depots, and in many cases facilities for ship repairs, have been provided along the main lines of our overseas trade at the more important ports. The advent of the flying machine will necessitate similar work being done again all over the world.

Just as railway trunk lines and the ocean trade arteries link up all the important points through which the British Empire conducts its export and import trade, so within large limits will the main-line air routes be traced out.

By reason of the wind currents of the upper air, about which not very much is known at present, the shortest aerial route between any two points may not coincide with the railway or steamer track or direct line. It is more than possible that a fair wind between any two points will usually be found, not necessarily on the direct line, but some distance away from it. In this way it may be far more economical to make a long detour in order to obtain a favourable wind than to proceed direct against a head wind. In this chapter, however, all distances are taken as the direct line from point to point.

Perhaps the best way to examine the world routes will be to follow more or less the main steamer tracks between Great Britain and the more important Colonial and foreign centres or the lines of transcontinental railways.

For the purposes of this review it is assumed that landing places and depots and other facilities will shortly after the declaration of peace be in existence—a not unreasonable assumption in view of the fact that such depots and landing places, constituting the "permanent way" of a flying service, can be provided at a cost of about one-three hundredth part of the cost for a similar length of railway line.

Let us now look more closely to the business application of flying. There are three main methods of doing business:

(a) Verbally—by personal visit or phone.
(b) By writing, either by letter or telegram.
(c) By samples which require transport.

In each of these three spheres aircraft has in the future a part to play.

(a) This is usually admitted to be the most desirable method, though time and distance often prevent a business man from using it. The aeroplane overcomes these difficulties easily.

(b) This method is resorted to where (a) is impossible, and also lends great scope for the flying machine.

(c) This really includes not merely samples of goods, but all printed matter which is wanted in a hurry, such as designs, plans, estimates, photographs and printed press matter, bonds, deeds, interest-bearing securities, powers of attorney, and many documents of a similar nature.

The carriage of goods also concerns the business man and is a very important question.

However important it may be, it can be dismissed in a very few words.

It is a generally accepted view that the fundamental basis underlying mechanical flight absolutely disposes of any possibility of carrying heavy or bulky goods by aeroplane, except in a few extraordinary cases. These few cases are those in which the intrinsic value of the cargo is so high compared to the cost of freight that the latter can be neglected.

Where these conditions obtain, and where the only other possible means of carriage involves a large outlay of capital (as would be required for building a railway over the Andes or Alps), the case for the carriage of goods by aeroplane is a strong one.

To mention one application in this direction, the writer was approached recently by a firm owning a wolfram mine who thought that they could carry their output more cheaply by aeroplane than by train by reason of the necessity for constructing a line forty miles long, laid so as to wind its way tortuously through valleys and mountain passes.

The proprietors of the mine were quite

correct, but on account of the war it was not possible to consider any such proposition, no aircraft being available for civil purposes.

A broad classification of all transport communication may be made by dividing them into four divisions :—

A. Aeroplane mail carriers and fast passenger service—average speed 100 miles per hour, night and day.

B. Aeroplane slow passenger service—average speed 80 miles per hour, day only.

C. Long-distance trains, 40 miles per hour, night and day.

D. Steamers, 15 miles per hour, night and day.

Roughly speaking, the time to be saved in each case is as follows :

| | Per cent |
|---|---|
| Flying machine compared with train | 50 |
| Flying machine compared with steamship . . . . . . | 90 |

This is not, as has been pointed out earlier in the chapter, a highly important matter in short journeys, and, perhaps, the saving would not be as great as here shown on account of the "terminal delays"—i.e. the time taken in getting to and from the aerodrome. But when we apply these figures to long routes we can see the great value of the flying machine as a time-saver.

Let us select a few long-distance routes for consideration:

| | Present Method of travelling. | | Future Method of travelling. | |
|---|---|---|---|---|
| | Single Journey. | Return Journey. | Single Journey. | Return Journey. |
| London to— | | | | |
| New York . | 5 days | 10 days | 30 hours | 60 hours |
| San Francisco . | 10 ,, | 20 ,, | 60 ,, | 5 days |
| Sydney . . | 35 ,, | 70 ,, | 5 ,, | 10 ,, |
| Cairo . . | 4½ ,, | 9 ,, | 18 hours | 36 hours |
| Bombay . . | 13 ,, | 26 ,, | 3 days | 6 days |
| Singapore. . | 19 ,, | 38 ,, | 3½ ,, | 7 ,, |
| Hong-kong . | 36 ,, | 72 ,, | 5 ,, | 10 ,, |
| Capetown . | 18 ,, | 36 | 60 hours | 5 ,, |
| Buenos Aires . | 19 ,, | 38 | 60 ,, | 5 ,, |
| Panama . . | 17 ,, | 34 | 60 ,, | 5 ,, |

Now, it is only the higher officials of any business concern who are generally required to make long journeys of this nature; therefore it is a fair assumption that the time value of such individuals would not be less than £1,500 per annum, or £4 a day.

It is not sufficient to consider the time necessary to get to a place; we must also consider the time occupied in getting back, and for that reason the time for the return journey is shown. The average time for any such long-distance journey as those given is thirty-six days there and back. This is approximately one-tenth of the working year.

So that if an official worth £1,500 per annum has to make one long journey the time lost—i.e. the number of days that he is away from his office—equals a tenth of his year's work; in other words, £150 is spent upon him by his employers as salary while he is out of the office for one long journey.

If, however, he had performed the same journey by aeroplane the total time so spent would have been about four days, worth, say, £15.

In both cases the fare has to be considered —in the first it would be about £100 and in the second it would be about £250. We therefore find that on the one hand the journey costs £150, *plus* £100=£250, and on the other about £15, *plus* £250=£265, or £15 more. But the advantages cannot be reckoned up merely according to the cost of time lost and the fare.

Again, on the one hand it may be impossible to send one of the chief officials on account of the time taken for the journey; valuable business is therefore either entirely neglected, or else a less responsible official has to be sent, in which case the results obtained may not be so satisfactory. On the other hand, if the flying machine is utilized a highly paid official can be sent, and advantage may be taken of all fleeting opportunities to do business which would otherwise be lost.

In addition to this, for every one long journey, taking on the average thirty-six days, eight or nine could be made by aeroplane, and consequently eight or nine times as much business done. It is in this way that the flying machine will help the business man in his efforts to be in two or more places at the same time.

It is not very easy to forecast what fares will be by flying machine, but as an estimate it would appear that from 4d. to 9d. a mile, according to the length of route, would be somewhere near the figure.

As regards the mail question. The saving of time would be the same, and it is also probable that methods of doing business might be modified by the saving of time obtained.

The question of samples may be considered at the same time; if a sample of wool or tobacco can be landed in London, say, three or five days after it arrives in the warehouse on the estate whence it is derived, the necessity for maintaining a staff of buyers at various parts of the world would be considerably lessened and an appreciable saving effected. The cost of carriage of such samples would be a drop in the ocean compared with the value of the business at stake, and could be figured out upon a basis of about 3s. 6d. per ton mile. This when dealing with packages weighing a few pounds would be a trifle.

In other commercial fields, perhaps the illustrated news agencies will be among the first to be affected in this way, for matter could be sent from London to New York in about twenty-four to thirty hours, or from Sydney in about 110 hours, or to Paris in about two hours, thus affecting to some extent the question of simultaneous publication.

All business men know the cost of cabling and how much trouble is entailed in coding and decoding cable messages. By reason of this high cost a great many cables are sent at " deferred " or week-end rates, where such delay is admissible. In some cases, therefore (that is to say when it is desired to send a long cable which is not a very urgent one), we may find that it will serve the business man's purpose just as well to send an " aerogram." This is because the deferred cables are often very much deferred on account of the large number of such messages waiting over, sometimes for many hours, if not days.

The rate per word of an aerogram could be considerably cheaper than the telegraphic rate per word. To convey a half-ounce of mail matter from London to Cape Town would cost the carriers somewhere about 3d. Into this half-ounce could be crammed probably 1,000 words. If such letters were conveyed at a rate of ½d. a word and a minimum charge of 1s. 6d., the business man should have little to complain of, for such a rate would appear to be strictly moderate, and the time, say, two and a half days, would not be excessive. In fact, there seems no reason why such a rate should not eventually be attained, and it appears that there is a distinct possibility that the deferred cable will find a young and vigorous competitor in the aerogram.

The aspect of safety must be taken into account, but where mails and samples only are concerned the risk does not appear likely to act as a deterrent, though where passengers are concerned it may—at first.

In view of the numerous fatalities that appear daily in the newspapers, it is only fair to state that these fatalities are either due to the action of the enemy or to the teaching of pupils how to fly under war conditions and against time. A trooper who wished to insure himself against death or injury in a cavalry charge against the enemy would not be surprised if underwriters asked fifty per cent or even declined the risk. If a man, however, wanted to insure himself during peace time against an accident in the hunting field he would find the premium a very insignificant matter. It is almost exactly similar in the case of war and peace flying.

It was said at the beginning of this article that the aeroplane except in rare circumstances could never be used as an economical carrier of goods. This is probably quite correct, but it is necessary to point out that in a vehicle like a flying machine, which can carry but a very limited weight of commodities, mails, or passengers, the essential of essentials is the weight of the consignment. We, therefore, have to resort to goods as well as passenger traffic terms in investigating aerial transport. For, in aerial matters, " passengers " must be looked upon as a special class of perishable goods, weighing, on an average, fourteen and a half to the ton ; so that, for the calculation of costs and fares, they are simply goods of a certain weight per piece.

As all men who have to do with railroad statistics will agree, a mere statement that a certain railway has carried so many tons during the year is quite useless. In the same way it would be useless to say that the total train mileage during the year was so many miles. To transport means to move a thing : the " thing " implies weight and the " movement" distance covered in the moving of the weight.

Railway statisticians in India and the United States of America at all events (and to some extent in this country) express the year's transportation work in "mile tons"—i.e. the number of tons loaded on to their trains multiplied by the miles over which they are transported, every consignment being weighed, and the weight multiplied by the length of the journey. Thus ten tons of potatoes moved from London to Edinburgh, a distance of 400 miles, gives a result of "4,000 ton miles."

In passenger returns passengers are substituted for tons, and the results are expressed in passenger miles. Ten passengers conveyed from London to Edinburgh would give 4,000 passenger miles. In aeronautical projects we may talk of passenger miles, we should have in mind all the time ton miles at fourteen and a half passengers to the ton.

The following statistics, which have been prepared with as near an approximation to accuracy as possible, will indicate where the flying machine has real advantages to offer.

In all transport questions the only accurate way of measuring the service performed is to use some combination of the articles moved with the distances through which they are moved.

Table A shows, in order of merit, the relative day's journey of the flying machine and its competitors, the day's work being assumed as twenty-four hours a day in all cases :

TABLE A

| | |
|---|---|
| Flying machine . . . . | 2,400 miles a day |
| Express train . . . . | 960 ,, ,, |
| Motor-car . . . . | 480 ,, ,, |
| Mail steamer . . . . | 360 ,, ,, |
| Goods train . . . . | 360 ,, ,, |
| Cargo steamer . . . | 240 ,, ,, |
| Road lorry . . . . | 120 ,, ,, |

The flying machine is easily first in point of distance travelled in the day.

Table B shows the cost per ton mile, in order of merit :

TABLE B

| | |
|---|---|
| Cargo steamer . . . | 1–100d. |
| Goods train . . . . | 1–25d. to 1–10d. |
| Road lorry . . . . | 1·5d. |
| Flying machine . . . | 9d. |

In this table the flying machine is hopelessly last.

Table C shows transportation capacity of the various vehicles:

TABLE C

| | | |
|---|---|---|
| Cargo steamer . . | 1,440,000 | ton miles per diem |
| Goods train . . | 100,000 | „ „ „ |
| Flying machine . | 4,800 | „ „ „ |
| Road lorry . . | 1,200 | „ „ „ |

In Table C the flying machine is again hopelessly outclassed, except by the road lorry.

Table D shows the passenger transportation capacity per diem:

TABLE D

| | | |
|---|---|---|
| Express train . | 288,000 | passenger miles per diem |
| Mail steamer . | 108,000 | „ „ „ |
| Flying machine | 72,000 | „ „ „ |
| Motor-car . | 2,400 | „ „ „ |

Here again, as the flying machine shows to poor advantage, the reader may begin to ask himself where the flying machine really does romp home an easy winner.

The next two tables speak for themselves.

Table E shows "salary cost" for a journey of 1,000 miles—i.e. the *pro rata* amount of salary paid during the duration of a thousand-mile journey (it being based upon an annual salary of £1,500 p.a., or, say, £4 a day:

TABLE E

| | £ | s. | d. |
|---|---|---|---|
| Flying machine | 1 | 15 | 0 |
| Express train | 4 | 0 | 0 |
| Motor-car | 8 | 0 | 0 |
| Mail steamer | 11 | 15 | 0 |
| Motor omnibus | 18 | 0 | 0 |

Table F shows the cost per mile to be added to the fare on account of salary incurred while travelling a distance of a mile :

TABLE F

| | |
|---|---|
| Flying machine | 0·4d. |
| Express train | 1d. |
| Motor-car | 2d. |
| Mail steamer | 2 2-3d. |
| Omnibus | 8d. |

| | | £ | s. | d. |
|---|---|---|---|---|
| London to Edinburgh, 400 miles, by train | = | 3 | 4 | 0 |
| add salary rate 400d. | = | 1 | 13 | 0 |
| Total cost | | 4 | 17 | 0 |

It is interesting to show how the figures may affect the cost of a journey, as manifested in the following examples :

| | £ | s. | d. |
|---|---|---|---|
| London to Edinburgh by flying machine at 4d. a mile = | 6 | 10 | 0 |
| add salary rate 160d. = | | 15 | 0 |
| Total cost | 7 | 5 | 0 |
| London to Cape Town by mail boat = | 45 | 0 | 0 |
| add salary rate, 6,000 miles at . 2–3d. = | 65 | 0 | 0 |
| Total cost | 110 | 0 | 0 |
| London to Cape Town by flying machine, say, 5d. a mile = | 120 | 0 | 0 |
| add salary rate = | 10 | 0 | 0 |
| Total cost | 130 | 0 | 0 |

These examples show how the salary rate per mile affects the ultimate cost of a business journey.

The present state of the science of aviation almost, if not quite, justifies the foreshadowings contained in this short article, though the transatlantic and transpacific routes will be difficult to solve. They will certainly not be regularly and commercially flown for some time yet.

What is lacking to make universal flying a possibility and a reality is the world-wide flying organization mentioned at the beginning of this article. A flying organization means the laying of a chain of depots, landing-places, refuges, repair depots, and fuel stations all over the world. A guess, though not a very wild guess, it is hoped, would put the amount of capital thus necessary for equipping the aerial permanent ways between London and the ten places named at from £600,000 to £800,000, about three hours of our present war expenditure.

To this must be added the cost of machines, say, another three hours' expenditure, or £750,000. By the expenditure of this comparatively small sum the best part of the globe could be linked up by a means of communication that would bring the outermost corners of the world within six days of London.

*The British Aircraft Industry*

# *The Flying Boat*

## *The Flying Boat* X

DURING the present war a new form of high-speed vehicle has made its appearance, and has rapidly been brought to a state of perfection. This new vehicle is the flying boat.

Though the flying boat is at this moment an engine of war, when peace is restored it will certainly be used as a commercial vehicle, its performance on war service having fully demonstrated its possibilities.

The flying boat is, of course, an offspring of the land flying machine, but it is different in certain respects ; while the wings and other flight organs are much the same as those of the ordinary flying machine, the fuselage or body of the machine is built in the form of a boat, thus adding to the machine some of the features and functions of a motor launch, or rather of a racing hydroplane boat.

The flying boat must not be confused with the seaplane. It is true that they both fly over the sea, but the likeness ends here. The public, who are not yet fully educated on the question of sea flying, are apt to consider that any aeroplane (other than a land machine) operating over and upon the sea is necessarily a seaplane. As a matter of fact this is very often the case, the reason being that large numbers of seaplanes had been built for our Admiralty before the flying boat had been fully recognized officially and taken up. Now that the advantages of the latter have been established they are beginning to take their place with the seaplane, though still in the minority.

To make clear the technical difference between the two one may say, in simple language, that if the landing wheels of the land machine are removed, and if a pair of box-shaped floats are substituted therefor, the land machine has been transformed into a seaplane. This was actually done in the early days of the war, and by this method the seaplane came into existence, though all the later types of seaplane were subsequently designed and built as seaplanes, and were not converted land machines. The real difference, then, between the two is that the seaplane is an adapted land machine, while the flying boat is, within limits, an adapted motor boat.

It may be thought that the flying boat is less well adapted to flying than the seaplane. In point of fact it certainly shows itself to be as satisfactory a flier as the seaplane, possibly a more satisfactory one. At the same time, as might be naturally expected, the flying boat is far better adapted for meeting the risks and dangers encountered upon the surface of the sea. In other words, while both types may be able to fly equally well, the advantage of seaworthiness lies entirely with the flying boat.

The first flying boat was conceived in the United States of America ; in point of size it was more a flying canoe than a boat. Its successors grew in dimensions, until, early in 1914 they had attained such proportions that Lieutenant Porte, R.N., in conjunction with an American financier, had made plans to fly across the Atlantic. The outbreak of war put an end to this project, and Lieutenant Porte came to England, where he introduced the American flying boat to the British Admiralty. From this beginning there has grown up a large aerial fleet of these boats. They are larger now than they were in 1914. They are also faster, and far more reliable. Their range of action has been enormously increased. In short, they have been improved from the stage of a mere experimental into that of a proved means of rapid transport.

Although one is not permitted to state exactly what the size, speed and load capacities of modern flying boats are, there is no harm in mentioning generalities. One may therefore state that the big flying boats of to-day, those suitable for oceanic flight, can maintain an average speed of about one hundred miles an hour. They can carry a maximum load of about three tons for a maximum distance of nearly 500 miles, without having to descend in order to refill with fuel; while, in lieu of a dead-weight cargo, an equivalent of nearly thirty passengers could be carried, if the present hulls were adapted to carrying such a bulky load.

All this great advance in mechanical flight has been achieved under conditions of war secrecy, so that the performances of these machines have not been noised abroad. Thus it has come about that, although we now have in our possession craft that could carry three tons weight from, say, Sydney to San Francisco, or vice versa, in about two and a half days, there are few people who know it —such a performance being quite undreamed of by probably 80 per cent of the white population of the world.

This short article does not aim at being either technical or historical—its purpose is rather to put before the travelling and commercial public some features of the business side of the flying boat as applied to " Aeroceanautics." (This word, which is new to the British language, has been minted to take the place of such phrases as " aeronautical ocean travel," " aerial transoceanic travel," etc. —all of them rather long to write, and tedious to repeat.)

Let us, therefore, examine the possibilities of a proposition for establishing a flying route between Australia and America.

In choosing the Pacific Ocean as the location of a sea flying service, the writer has not been misled by the name Pacific. He has chosen this part of the ocean because, with the exception of one other, namely, the Caribbean Sea, there is no part of the world which lends itself so pre-eminently to such a service, judging from either the meteorological, commercial, or geographical point of view.

Distances in the Pacific are great, and steamships are slow, while sailing schooners are slower still. There are points between many of which rapid transport would be a boon. The provision of *rapid, or even frequent*, communication between them can never be provided except by aeroplane, because there is not sufficient commercial inducement to pay for the expense of providing it by any other means.

While the transatlantic flight may be a more popular theme, and one which is continually mentioned as the next great aeronautical achievement, the present writer looks upon it as a proposition unlikely to be regularly and commercially carried out for many years to come. Weather, and other conditions, are altogether against it. On the other hand, the transpacific flight appears to have far more probability of becoming a commercial reality.

The meteorological conditions are good, the climate is warm and generous, and, though there are many violent storms in the Pacific, they are chiefly rather local in nature, not very long of duration, and, most important of all, while they can be clearly and unmistakably forecasted, they do not leave the surface of the ocean sullen and irritated for long periods after they have passed away, like the gales of the North Atlantic, which during the greater part of the winter is turbulent and stormy.

Geographical conditions are also nearly ideal, for every few hundred miles are to be found groups of islands forming sheltered spots where flying craft could take refuge or refill their fuel tanks.

It will be asked, " Is there anything in it ? "

Though this question is almost impossible to answer, there are strong reasons for thinking that there is. The success of such a service would depend, primarily, upon the amount of transportation to be done, other conditions being satisfactory. It is better to consider mails and passengers apart, and as it is likely that mails will be regularly carried by air before passengers (who might require persuasion as to the safety of such methods of travelling), the author will state first of all how the mail question appears to him.

The weight of mail matter, according to the annual report of the Postmaster-General, carried inwards and outwards between Great Britain and Australia and New Zealand for the last pre-war year was approximately 4,000 tons, rather more than half of which was outward from the United Kingdom and rather less than half was inward to the United Kingdom. Suppose, therefore, that Australia could be reached in five or six days either via Europe and the Malay Peninsula or via the United States of America and Honolulu, and that the competing routes would share half the available traffic—that is to say, one half of the total traffic would be sent by one route and the other half by the other route—a maximum of about 2,000 tons per annum, total out and home, would possibly be available during the year along each route.

One must not assume, however, that the whole of the public who correspond with Australia and New Zealand would suddenly avail themselves of this new form of mail service; probably only one half of the mail —i.e. that comprising newspapers, business letters, and samples—would at first be carried. Upon this, the assumption is made that the mail to Great Britain via the United States would be about 400 tons, while the mail in the reverse direction would be about 600 tons per annum.

To this, however, must be added a proportion of the present mail between the United States of America and our Antipodean Colonies. Though the exact figures for this are not available, it would appear from a perusal of the Postmaster-General's report to be not much less than 250 tons a year each way from and to America. If we allot 100 tons of this to the aerial route in each direction, we would have 500 tons from Australia and New Zealand to Great Britain and the United States, and 700 tons into the Commonwealth, via the Pacific.

This gives a working idea of how much mail matter would have to be carried—some fifteen tons per week from, and about ten tons per week to the States. To keep on the safe side, however, we will consider that there are only nine tons each way. To carry this, three flying boats, each capable of carrying three tons, would be required weekly in each direction.

The investigation so far has been towards discovering whether there would be any quantity of mails to carry; it seems a fair assumption that there would, and that passenger carrying as a feature necessary to make the service pay can therefore be ignored—though, as a matter of interest, an indication of possible fares is given later.

The next question to consider is what would be the saving in time. It should not be necessary to draw the business man's attention to this. However, as no machine has ever been invented which is such a time saver as the flying machine (which will give to the word "time" an aspect never before dreamt of), some comparative tables showing the time saved are given below:

| | Steam Ship. | Sailing Schooner. | Flying Boat. | Time Saved. |
|---|---|---|---|---|
| *London–Sydney . . | 32 days | | 5 days | 27 days |
| *Return . . . . | 64 " | | 10 " | 54 " |
| Sydney–Fiji . . . | 6 " | 14 days | 20-24 hours | 5-13 " |
| Return . . . . | 12 " | 28 " | 2 days | 10-26 " |
| Sydney–San Francisco . | 19 " | | 2½-3 " | 16 " |
| Return . . . . | 38 " | | 5-6 " | 31-32 " |
| Fiji–Samoa . . . | 3 " | 10 " | 6-7 hours | 2½-9½ " |
| Return . . . . | 6 " | 20 " | 12-14 " | 5-19 " |
| Samoa, Fiji, New Hebrides, Solomon Islands (subject to connexions) | 30 " | 2 months | 1 day | 1-2 months |
| Return . . . . | 2 months | 4 " | 2 days | 2-4 " |

* This is via Malay Peninsula, and though it does not strictly come within the scope of this scheme it is inserted by way of comparison.

This table shows plainly that journeys "across country" hitherto almost commercially impossible on account of the time taken can be speedily and comfortably carried out in a few hours or at most in a few days. This fact has a distinct business significance.

Calculations in the question of aeroplane maintenance and running, based upon experience gained in pre-war days, and modified by recent experience with machines built since the war, indicate that the all-in cost of running a flying boat after the war, as a commercial proposition, should not exceed 1s. 6d. per mile—this figure including fuel, repairs, insurance, depreciation, pilots, office expense, and all maintenance charges. This would give the actual cost of flying a machine from Sydney to San Francisco as about £500.

Dividing the journey into stages, we can gain a rough approximation of the postal rates necessary to make a profit. Sydney, Brisbane, Mayborough, New Caledonia, New Hebrides, and Fiji, 1½d. an ounce; islands between Fiji and Hawaii, 3d. an ounce; Hawaii and San Francisco, 4½d. an ounce. However, if the payment for letters and parcels between Sydney and San Francisco averaged only 2d. an ounce, and three tons were carried per trip, the receipts per trip would amount to £750.

As to passengers, with a maximum of about thirty and an average number of about twenty-five, the cost per passenger mile would average about three farthings to a penny a mile. The fare would depend, of course, largely upon the number of passengers ; it might eventually be £20–£30 between Sydney and San Francisco.

Now that we have glanced at the preliminary financial features, let us recapitulate some of the possibilities resulting from the establishment of such a service.

First, the United States of America would be only some two and a half days from Australia, that is, a saving of nearly three weeks on the single journey. In addition to this there would be a three times a week service ; this would be a point of interest to the business men of Australia and the United States. There are, however, others who would find out the advantages of such a service—namely, those who inhabit, or have to deal with, the coast towns and island groups lying along or near to the track of the flying boat.

Let us dwell upon the convenience of getting from Sydney to Brisbane in six hours in a swift and comfortable vehicle, steadier than a ship, quieter, cleaner, and smoother than any train that ever ran, with neither crowded, stuffy cabins, nor sooty, sun-scorched railway compartments; a marvellous and refreshing panorama to interest one all the way along the coast line, and all the fresh air that anyone could want. One could have breakfast in Sydney, luncheon at Brisbane, and be back at Sydney by bedtime after having done one's business.

Again, many of the islands near the route are at present more or less inaccessible. How many months, for example, does it take in normal times to make a round trip between New Caledonia, New Hebrides, Fiji, and Samoa, allowing for contrary winds and missed connections? What of the discomforts and the lost time? All these islands would benefit by the scheme.

The general line of the proposed service would be from Sydney to Fiji via Brisbane, Mayborough, the outliers of the New Caledonia group, and New Hebrides: thence via Samoa, Manahiki, Malden, Fanning, and

Palmyra Islands to Honolulu. From Honolulu to San Francisco the route would be pretty well direct unless a favourable wind be found to exist making it worth while to deviate from the straight path. This question of deviation to obtain favourable winds is one which has yet to be scientifically investigated, and need not be discussed here.

Though the radius of action of a flying boat such as would be used on this service would be 500 to 600 miles, it would be necessary for a refuge of some kind to be provided every 200 miles or so, at which fuel and stores could be replenished, and shelter provided in bad weather. This would create a tendency to locate the route from one island to the next, wherever such islands can be found at convenient intervals. However, these islands do not always exist at the right places, and it would therefore be necessary to supplement the natural resting and refilling points by artificial ones.

These would take the form of small depot ships of 150 to 200 tons, placed where wanted and kept in their position by astronomical observation. There would be a chain of them between Honolulu and San Francisco, while a few more would be required between Fanning Island and Honolulu, and possibly one or two in the Sydney-Fiji section. Their functions would be firstly, to act as fuel depots for flying boats, and to provide refreshments for passengers and pilots; secondly, to act as weather sentinels all along the route.

The most important point in aeroceanautics is the weather. This is not because flying boats cannot fly in bad weather. They certainly can, and in point of fact they have been flying the North Sea by night and by day in all kinds of weather for the last three years. It is far less the conditions of the air that matter than the condition of the sea. The depot ships would have to keep an incessant meteorological look out, in order that pilots might be warned of the conditions expected some hours in advance.

It should be remembered that the flying machine is not yet so perfectly reliable that it is never forced to descend. When one of these forced descents has to be made it is always more comfortable for pilot and passengers and less exacting upon the machine if the surface of the sea is tolerably smooth. In short, to descend into the sea during a heavy storm will always be avoided if possible, until the day when the size of the machines makes them independent of surface conditions.

These chains of look-outs all along the route, each supplied with meteorological instruments and fitted with wireless telegraphy, should make an impossibility of such undesirable contingencies. When such unfavourable conditions happen to exist the pilot would simply wait till the " clouds rolled by," never a very long wait in the Pacific.

The captious may here see a flaw in the project, and they may say that the mail-ship is never held back by the weather, and seldom much delayed by it, whereas the flying boat might have to wait for days and days. That is true ; but, misapplying the principle of the hare and the tortoise, the flying boat might be delayed for a week and get in days before the mail-boat—though such lengthy delays would be exceptional.

It may interest the readers of this article to know how the boats will be steered on their course when no landmarks can be seen. The probability is that all landing points, depot ships, etc., would be provided with vertical searchlights. These lights, though not actually visible to the pilots beyond a distance of a few miles, would cast a glare into the sky which would be visible at any distance up to 100 miles, perhaps more. The writer actually knows from personal experience that the glare of horizontal coastal searchlights can be seen at ninety miles' distance in the tropics from the level of a ship's bridge. The value of the searchlight, however, may be discounted by a recent development of wireless telegraphy, by which flying machines will eventually be directed to unseen havens.

Though flying is at present comparatively dangerous, it must be remembered that it is now carried out under war conditions. It is a fact that the bulk of our pilots spend a considerable part of their flying time in endeavouring to kill, or in learning to kill, Germans—an operation which naturally involves the taking of every kind of risk.

Let us look once more at the business features of the proposition, which can be shortly summed up as follows:

Capital outlay for provision of landing-places, depots, stores, buildings, hangars, motor-launches, electric-light plants, wireless apparatus, workshops, and all such charges can be put down at approximately £25 per mile of route.

As the length of the route is approximately 6,000 miles, the capital outlay for the "permanent way" would be, in round figures, £150,000.

The capital expenditure for the "rolling stock," or rather the "flying stock"—i.e. the machines—at about £8,000 each, assuming that four would be required to run the service and that another three would be kept in reserve, would amount to £56,000. This makes a total of £206,000, which, with an extra £44,000 as working capital, brings the total capital to £250,000.

The inclusive costs, as mentioned elsewhere, are taken at 1s. 6d. per mile flown.

From this it is simple to make a statement as to the possibilities of such a scheme maintaining itself.

An average charge of 2d. per ounce from Sydney to San Francisco would give the takings for one single trip, with a load of three tons, as £750 in round figures; the actual cost per trip would be approximately £500, leaving a net profit of nearly £200 per trip, or nearly £400 for each double trip.

There are 156 double trips in the year, giving a result of over £60,000 per annum, after paying for all maintenance and operating charges, repairs and depreciation, and insurance.

It will be seen therefore that the aerial transport of mails over long sea routes may provide a means of communication which, while being cheap and speedy, has a reasonable chance of paying its own way.

Though this article has not dealt with the matter of inter-island and local services, there is a large scope for such services among certain groups. These local routes would be maintained by smaller boats carrying from eight to ten passengers, and costing from 9d. to 1s. per mile to run and maintain. Their capital cost would be about £4,000 apiece, while the cost of the permanent way would probably not exceed £15–£20 a mile.

This chapter gives but a sketch of what may and, indeed, can be expected in the not very distant future, and though much more could have been said, it may be of interest to those who read it. It is written upon a new subject, one in which all the data are not as yet perfectly known. It may, like most new projects, be the subject of criticism ; the writer hopes that it will, for such criticism will prove the existence of an interest in the development of flying as a real and commercially tangible means of transportation.

# *Flying as a Sport*

## *Flying as a Sport* XI

AERONAUTICS as a sport, and apart from the flying of Service machines, or of mail and passenger craft, will probably after the war have two main aspects: (1) aerial racing; and (2) touring and pleasure flying.

The former will not, of course, be altogether a novelty, though contests more exciting than those before the war should be possible. That aerial racing could be made attractive even then, when public interest in flying was much less keen than it is now, was demonstrated very clearly at the London Aerodrome, where as many as 60,000 spectators gathered to see an Aerial Derby; while at this same aerodrome some of the world's best pilots, flying aeroplanes which were, at that time, the finest that designers and constructors could produce, met in a rivalry which had a beneficial influence not only upon the public, who were interested and instructed by all they saw, but also upon the whole design and building of heavier-than-air machines.

After the war, although people will, of course, be much more familiar than they were with the sight of an aeroplane in flight, and will expect in consequence a more ambitious programme, every effort should, I hold, be made to encourage and stimulate aerial racing. Motor-car racing, marred though it was by fatalities, had an enormously important influence on design, particularly from the point of view of securing a greater reliability for parts which are subjected to strain; and air racing, which was only in its infancy before the war, will probably help us materially in post-war days to gain that dependability in actual running which will be so vital a feature of the commercial machine.

There is the human element to be remembered also. The champion air racer, a man of exceptional nerve and skill, capable of doing things with an aeroplane that other men cannot do, may prove of almost priceless value in a national emergency; while his ability to test thoroughly any new type of high-speed craft should also prove most useful. We must not forget that it will be the speed of aerial transit which will enable it to compete successfully with land and sea transit.

It is argued that people will not come to see flying contests after the war as they did before; but this, after all, is a question which depends mainly on the ability of the organizers of such contests to provide a sufficiently attractive programme. If the races are exciting, and if the speeds attained are sufficiently great to cause—as they probably will—something of a sensation, then there is no doubt that meetings will be well attended. Contests of an international character should be specially attractive; while there are almost unlimited possibilities in the way of displays and demonstrations by pilots who are experts in some special branch of their art. It must not be forgotten, with regard to the very large number of young men, drawn from all professions and classes of society, who have become pilots during the war, and are likely to play a part in post-war sporting events, that the relations and friends of such pilots, anxious naturally to see how they acquit themselves, should provide at the race meetings quite an appreciable concourse of personally interested spectators.

What might prove most valuable would be some large demonstration of flying, held as soon as possible after the war, and under the auspices of the Governments of the Allies. This could be made to reveal the marvellous progress of aeronautics, and more especially could show how this progress may be turned to good account in the production of commercial and pleasure machines. Such a demonstration might be given in turn in all the great cities of the Allies, and its educative influence would certainly prove immense. The demonstration might take the form of a series of contests and displays lasting for a fortnight; and in the London programme there might, for instance, be a race to Paris, Rome, and back, to show the possibilities of the aeroplane for long-distance commercial flying. Another contest might be framed so as to show the ability of machines to fly regularly to scheduled times either by day or night. Night flying, in regard to the carriage of mails, may be specially important.

It seems clear that there will be many pilots now in the Services who, on returning to private life after the war, will be extremely glad to continue their association with aeronautics, and to enjoy at least an occasional flight. That such men should keep in touch with flying is, quite apart from their own pleasure, most desirable from the national point of view. It has been suggested that, in order to lessen their expenses, in the early days of civil aerial transport, they should become members of flying clubs, which could be established with their headquarters at suitably equipped aerodromes. The aim of such clubs would be, by organized co-operative effort, to reduce, as far as possible, the cost of flying to the individual.

Another possibility for the man who desires to fly, and who feels at the same time that he would like to place some limit on his responsibility and expense, is to buy a machine and then entrust all questions as to its upkeep and running cost to some aerial transport company, who would house the machine at their own aerodrome, keep it constantly in trim, and provide also a suitable pilot from their own staff. In such a case the owner would simply telephone when he wanted to come out to the aerodrome for a flight, and would be spared all other troubles or delays.

But there will be ardent pioneers, no doubt, as there were in the early days of the motor-car, who will not want everything made easy for them—men who have money with which to buy their own experience, and who will find a sporting zest in the adventures, humorous and otherwise, which come their way. Such individual sportsmen, who may do so much to popularize the aeroplane for touring, should be welcomed very heartily by the industry as soon as peace comes; and it is to be hoped that some of them, apart from purely pleasure flying, will learn to use their aeroplanes, instead of their motor-cars, in travelling up from the country to attend their offices in town, or when they are called upon, say, to make an urgent trip to Paris.

To such men, who will want to house and run an aeroplane as they would a motor-car, the cost of flying, even immediately after the war, should not be prohibitive. A well-equipped touring machine, seating, say, four passengers and a driver, may cost between £1,500 and £2,000; or, if materials are hard to procure, perhaps a little more. The life of such a machine, when well looked after, should be almost as long as that of a motor-car; but its upkeep, at any rate for some time after the war, will cost more probably than that of a car. Eventually, however, the maintenance of an aeroplane should cost appreciably less than that of a motor-car. The tyre bill of the aeroplane will, for instance, be negligible.

The private owner who wishes to erect in his own grounds a garage for the housing of an aeroplane will find probably that a building which has a pleasant appearance, is electrically lit and heated, and has a water supply, will cost him from £1,000 to £1,500, though it might be quite possible to erect a simpler building for about £500.

It will be very necessary, in cases where the private owner wishes to ascend from, and alight on, his own private park or field, that this should be of a size sufficient for the safe manœuvring of a machine. What will be required is a smooth, open space 400 or 500 yards long and about 300 yards wide, with no seriously high obstacles, such as trees or chimneys, in the immediate neighbourhood. When, however, the direction of the wind entails an ascent being made crossways, instead of lengthways, of such a ground, it might scarcely be considered ideal, but a skilled pilot should have no difficulty, except in really bad weather—and then the owner would not probably want to fly at all.

The wages of an experienced pilot-mechanic—a man competent to fly an aeroplane and also to keep it in trim—should be about £5 or £6 a week; and if this man could obtain occasional help from other workers on an estate he should be able to do all that is normally required. Several men might, however, be needed to help in getting a machine in or out of a shed, but gardeners or others would be quite competent to render such assistance as this.

As to the actual cost of running a five-seated machine such as has been described—taking petrol and oil at their present prices, and assuming " give-and-take " weather conditions —I should estimate this at between 1s. 6d. and 2s. per mile.

Another item which the private owner would need to consider is that of insurance, and here a policy covering the machine, owner, and driver in Great Britain, and providing also against third-party risks, might represent an annual expenditure of something like £200.

## *The Work of the Aeronautical Society*

NO general record of the Aircraft Industry, such as is given in the present number, would be complete without an account of the fine work done by the Aeronautical Society of Great Britain during its fifty years' life.

It is sometimes forgotten that it is the premier scientific institution in the world dealing with aeronautics, and has always displayed great activity in promoting research work on subjects connected with flight, the construction of aircraft, and in stimulating public interest in the military and social problems involved. What has been achieved has given the society the status of the only British professional organization for this branch of engineering. Practically all those associated with the scientific aspects of aviation are Fellows of the society, and have all been on the membership roll from the early days of Glaisher, Stringfellow, Pilcher, Wenham, and the other pioneers of the balloon and aeroplane to Wilbur and Orville Wright, Cody and Farman.

To-day the Aeronautical Society is rapidly advancing in position and influence. The chairman, Major-General Ruck, C.B., R.E., is vice-chairman of the Air Inventions Committee, and other members of the council include Mr. G. Holt Thomas, Mr. Handley Page, Lieutenant-Colonel O'Gorman, and Dr. Stanton, of the National Physical Laboratory. The secretary of the society is Mr. Barnard Faraday, a decided acquisition to aeronautics.

It is sometimes supposed that the early activities of the society were confined to ballooning. This is an entire error. For over fifty years the society has been investigating ing and experimenting with heavier-than-air machines, and among its most valued possessions are the model made by Stringfellow in 1842, the first engine-driven aeroplane to fly, and the glider upon which Pilcher was killed a quarter of a century ago.

The question of the standardization of aeronautical terminology is an urgent one, and the society has this year undertaken the laborious and necessary work involved in its solution. It has nominated a committee to deal with the matter to which representatives of the Air Ministry, War Office, Admiralty, Patent Office, Advisory Committee on Aeronautics, Society of British Aircraft Constructors, Royal Aero Club, and Meteorological Office have been appointed. This committee also acts as the Aeronautical Nomenclature Committee of the Engineering Standards Committee, and its results will be published at an early date. It is acting in consultation with the National Advisory Committee on Aeronautics of the United States.

The society arranges lectures frequently, and these disclose so much of the latest research in scientific aeronautics as at the present time it is advisable to publish. The society has also conducted courses of educational lectures this year in all the principal centres of the aircraft industry. It is at the present time probably the most active and enthusiastic of all the learned societies.

# *The Future of the Aircraft Industry*

## *The Future of the Aircraft Industry* *XIII*

THE history of the present war has shown us that we in this country were not prepared for it, particularly in the provision of aircraft; that we underestimated the strength of our opponents, and failed to make provision for the fact that a desperate nation may adopt unrecognized methods in warfare.

Let this country, therefore, make up for its pre-war neglect of aviation by being prepared for the next great war—the commercial war, that must assuredly follow. British aviation must be supreme when our great industrial armies enter the battlefields of commerce. We must see to it that the strength and methods of our competitors are not underestimated.

The British aircraft industry has shown during the present war that machines of British design and manufacture are second to none, and if these results can be achieved in spite of present-day difficulties and disorganization, it is up to us to maintain this supremacy after the war.

At the present time the production of aircraft for war purposes is in the hands of two classes of manufacturer—the originating or designing firms, and those engaged simply on " copying " their designs in repetition quantities. The aircraft industry and those firms temporarily associated with it have put the whole of their energies into this work, and the few factories which existed prior to the war have been enlarged to twenty times their pre-war capacity.

Great factories have been erected for the manufacture of aircraft on repetition lines, and many new concerns have laid down plant for the production of aircraft for immediate war purposes and to provide commercial aircraft for use after the war.

Important engineering and wood-working firms, formerly employed on the manufacture of machinery, motor-cars, furniture, pianos, shop fittings, etc., have enlarged their works and turned these over for the production of aeroplanes and aero-engines for urgent naval and military requirements.

The conditions under which all these factories are working are entirely different from the conditions that will prevail when peace comes, and probably only a few far-seeing manufacturers have begun to examine the possible development of aeronautics at the end of the war.

At the present time, although the manufacturer experiences great difficulty with regard to obtaining supplies of controlled materials and labour, and a certain amount of " disorganized organization " due to the indefinite air policy adopted in the first two or three years of the war, his profits are more or less assured, so far as the war is concerned, and the whole of his output is being taken at a fair price, but by one customer only—the Air Ministry.

There is little or no competition, and the manufacturer does not require a sales organization to place the merits of his production before a large number of possible purchasers and to provide for the competition of other manufacturers in the open markets.

When the war ends the air force will remain, and in view of the fact that this new arm is to play the first part in the future defence of this country, it is certain also that it will expand a great deal within a few years, and its requirements increase in proportion. The demand for aircraft for the equipment of the air force during the first year of peace will be small, for, although the types required for future naval and military use will differ considerably from the machines now employed, our reserve equipment of machines at the end of the war will be so large that the authorities will not be in a position to place new contracts for some considerable time, with the exception, of course, of orders for a certain number of experimental and special types.

There will possibly be little demand for the first twelve months after the war for aircraft for private, commercial, or military purposes. This period will be spent by manufacturers in reorganization, experimental work, the preparation of a definite policy and the creation of a "sales" department. The problem, therefore, which presents itself of finding suitable work for at least the first year of peace for firms now employed on the production of aircraft is a very serious one, and the question of tiding over this period of suspension so as definitely to attain and maintain commercial supremacy for British aviation demands initiative, foresight, and co-operation.

The furniture and motor-car factories, with certain exceptions, will return to their former work with the capacity of their shops very much increased. In many cases the latter will still continue the design and manufacture of aero-engines for the aircraft industry.

Aircraft factories, with the exception of a few firms whose designs and organization are such as to give them an advantage over others, must, in order to keep their shops employed, place the larger portion of their works on the production of commodities for which there is an immediate demand, such as ships' fittings, builders' joinery and equipment, office and household furniture, motor-cars and motor-cycles, electrical fittings, pianos, motor-boats, sewing machines, etc.

During this period they will carry on experimental work and a certain amount of manufacturing of aircraft to assist in developing this side of their business, so as to be ready to meet the demand for aircraft which will be in process of development during that period. There are many large aircraft firms who at the present time have no designing staffs, and who are engaged simply on the repetition production of machines of either Government design or designed by some other private firm. These firms will have to organize an efficient designing staff, and it will consequently take some considerable time before they will be in a position to create a demand for machines of their own design.

The Minister of Reconstruction has appointed a committee to consider the provision of new industries for the engineering trades after the war. Its principal duty will be to recommend certain articles suitable for manufacture by British engineers which were either not made in the United Kingdom or were made in insufficient quantities, and for which there will be a demand after the war.

These are to be classified into articles that can be made by skilled, semi-skilled, and unskilled workers and by women.

It is hoped that special consideration will be given to the provision of work suitable for manufacture by aircraft factories during the " dead " period after the war, and to its organization on such lines that these factories will be able to keep their works fully occupied and retain their highly trained administrative staffs and workers, so that they can revert to the production of aircraft in commercial quantities immediately the demand has been created.

Up to the present, owing to war pressure, British aircraft constructors have had no opportunity to produce machines specifically designed for private or commercial purposes, but there is no doubt that several of the types now being used for war purposes will be suitable for the present to meet certain peace-time requirements ; for instance, machines of the big Handley-Page " bomber " type and our large flying boats will conceivably be types adaptable for the carrying of mails, merchandise, and for passenger transit services. Flying boats of the small " Curtiss " type, and " Avro " and other two-seater types of aeroplane, will be suitable for pleasure touring, and machines of the " Sopwith " Scout type will be used for racing and for purposes where high speeds are required.

The writer has recently heard of an enterprising aircraft manufacturer who proposes to put on the market immediately after the war a two-seater dual-control biplane, with an 80–100-h.p. engine designed for a speed of about 80 miles per hour, for £600 complete ; and for an additional £150 he will provide a collapsible hangar in which to house the machine. This is a step in the right direction, as the demand for aircraft for pleasure touring purposes will certainly be one of the first to assert itself.

For a few pounds per week the private owner will be able to employ the services of a skilled pilot for the purpose of " getting off " and landing, the owner piloting the machine while in the air. It is not universally known that the most difficult part of flying is in learning to " get away " and land properly, the control of the machine in the air being a comparatively easy matter.

The question of touring will very much depend upon what arrangements will be made for the provision of a route of suitable aerodromes throughout the country. Probably the military authorities will be prepared to lease a large number of the aerodromes which are now being used for military purposes to firms or individuals who would undertake to keep these in good repair, reserving the right to take them over again when required.

A large number of civilian flying schools will be established throughout the country and the demand for machines for the purposes of tuition will probably also be very large. It is probable, also, that many aircraft firms will organize and maintain schools of their own.

In addition to pleasure touring and school machines, referred to, it is certain that an early demand will be made for machines expressly designed and built for mail-carrying services, and this is a question which will receive a great deal of attention in the very near future.

The demand for naval and military aircraft for the various Powers will also be very large, and there will be severe competition between the aircraft designing and producing countries for this business.

Racing and competitions, both at aerodromes and over long cross-country routes, will be an important factor in the development of aircraft, and there will be a market for sporting aircraft of high speeds.

One of the first air races will probably be an "Aerial Derby," being a double circuit of London, a total distance of about 200 miles, the race starting and finishing in about an hour and a half.

Exhibitions and passenger-carrying flights at those aerodromes which adjoin large towns will still be popular among the general public.

It is difficult to predict what progress will be made in aeronautics with regard to the transit of goods, but the early future will see the establishment of several passenger-carrying services maintained on sound and profitable lines, the first being a cross-Channel service, and a little later a service probably from London to Paris.

It is difficult to predict what progress will be made in this or other countries with "lighter-than-air" craft. As far as we can learn from experience to date, the initial cost and the cost of accommodation and maintenance of airships render this form of aerial transit a doubtful commercial proposition. In view, however, of a possible demand, at least for naval purposes, there is no doubt that the possibilities of the airship will not be overlooked by the aircraft industry in this country.

When the war broke out the motor-car factories, representing a flourishing industry, were ready and able successfully to adapt their productions to meet requirements for war purposes. The aircraft industry, neglected but not discouraged, found itself unprepared for the enormous demands made upon it; nevertheless, it has, working under great pressure and difficulties, made wonderful progress.

It has been said that the wars of the future will be fought in the air, and will undoubtedly be won by that nation possessing in addition to a strong air fleet the largest reserve of pilots, commercial and other aircraft, and of aircraft factories which can be called upon in case of emergency. From this point of view it is obvious how important it is to us that commercial aviation and flying generally should be encouraged in every possible way. All the great industrial traffic and commercial interests should co-operate to this end, and every facility and encouragement be given by the Government and the naval and military authorities.

In order that British aircraft shall be in a position to compete on a fair basis in the home and export markets with foreign competition, it will be desirable that some co-operative scheme of standardization and centralization of manufacture of parts shall be put into operation.

Manufacturers will find it necessary to employ capable experimental pilots in addition to their designing staffs, and success and progress are practically assured where a clever designer works in close co-operation with a sound, intelligent experimental pilot.

It is probable that manufacturers will confine themselves to a study of one or two types of machine ; that is to say, firms engaged on the design and production of machines for pleasure purposes will probably leave the work of providing machines for commercial purposes in other hands. This policy of specialization would certainly do much to ensure commercial supremacy for British aviation.

Careful attention must be given to the design and production of efficient and reliable aero-engines, for it is absolutely necessary, if we are to succeed in establishing ourselves in the markets of the world, that British aircraft of all types should be fitted with British engines.

We have learnt a great deal from our experience in building aircraft for war purposes. We have made many mistakes, and yet we have been extraordinarily successful. When we come " to set our house in order " we must use our knowledge so as to succeed in providing for the requirements of the commercial world on lines that will ensure the maintenance of British prestige in this new and rapidly developing industry.

Commercial supremacy will mean that this country must be in a position to supply aircraft for commercial and private use in large quantities, and the price should be such as will compare favourably with other competitors. The workmanship should be up to recognized British engineering standard, and the design should ensure maximum efficiency and performance, simple and easy control ability, and, above all, reliability of the engine and of construction of the machine should be the outstanding features. These qualities are not to be attained without effort, and there is no doubt that we shall see to it that the aircraft industry in this country will represent British enterprise as successfully as it is represented by other British engineering industries.

In order to compete successfully in foreign markets, the question of efficient and economical production of aircraft in commercial quantities has yet to be placed on a definite basis. When the real demand for aircraft arrives, factories will be able to lay down plans for the construction of a large number of machines of the same type, and proper foresight should be used in the arrangement of workshop methods in order that these shall be turned out quickly and cheaply without necessarily affecting the quality, safety, or efficiency of the machines. In this connection, however, there is an important point which must be provided for, and that is, that the continued development in design will be so constant and rapid that provision will have to be made for necessary alterations to types during the process of manufacture in quantities. There is no fear, however, that British aeronautical production engineers will be lacking in resource in this respect.

There are two very important considerations which will materially affect progress after the war. One is the question of "patent rights" and the other the question of "insurance." It will be a surprise to most people to know that, with the exception of a few trifling details which are covered by patents, there are few points in even our very latest types of aircraft that are patentable propositions, and that apparently there is nothing to prevent anybody building machines similar to the productions of our most successful manufacturers, provided that they are in a position to ascertain the detail dimensions.

The modern aeroplane has developed quickly mainly owing to its freedom from patented details, the improvements being a question, usually, of alterations in surfaces, angles, and streamline design, etc.

Some provision must be made so that manufacturers will be in a position to protect their designs against unfair imitation.

The second point—i.e. " insurance "—is also an extremely important one, affecting rapid development after the war.

The demand for insurances against accident to aircraft or to third parties will be very great, and unless the premiums quoted are such as to make flying a commercial proposition, the use of aircraft for commercial and pleasure purposes will be seriously restricted.

A committee of Lloyd's Underwriters should be set up without delay, to ascertain how the interests of British aviation can best be served by insurance.

The development of commercial aviation in this country will also depend to a very large extent on the nature of the laws governing aerial traffic which it is proposed to bring into operation after the war. The framing of these will require much care, and their application much consideration, so that they will not prove a hindrance to the development and issue of aircraft, and, in fact, they should be prepared so as to assist and encourage in every possible way, after providing reasonably for the safety of the public. This is a matter to which immediate attention should be given by the Society of British Aircraft Constructors, which represents the interests of aircraft manufacturers in this country, and by those other bodies which now, or may in the future, represent the users of commercial or private aircraft.

The amount of capital invested in the aircraft industry is now enormous, and this is represented by plant, machinery, huge factories and aerodromes, ready to be employed seriously upon the task of providing a future for commercial aviation in this country on a sound basis. In order that development shall continue on the right lines, some control should be exercised over the mushroom aviation schemes that are bound to be put before the British investor after the war, and which, if they succeed in attracting capital from the investing public, will be bound seriously to affect the credit of the British aircraft industry, and consequently to retard its progress.

We now come to the question of the establishment of a selling organization in an aircraft factory.

Successful competition is not covered simply by the manufacturer's ability to sell a better article at a lower price.

The aircraft manufacturer's work does not end when he has succeeded in producing a reliable machine giving a better performance at a lower price than his competitor. He must next succeed in interesting the purchaser in his productions, and convince him of their superiority over those of other competitors.

There are few, if any, aircraft manufacturers in this country who possess a properly organized selling department, and it is essential, therefore, that serious consideration should be given to this point without further delay.

The business of selling is quite as important as the business of manufacturing, and those firms who do not within a few months after the declaration of peace prepare a well-organized selling policy, to be directed and carried on from offices in London, will find themselves at a considerable disadvantage with others who are more enterprising.

It will be necessary for them to send or to appoint reliable and capable agents abroad who are in a position to represent their interests, and also keep their principals in touch with every development, or some manufacturers would prefer to send machines in charge of a competent engineer and pilot to give demonstrations.

Firms will also find it necessary, in order that their productions may become well known, to advertise intelligently in the various British and Continental aviation and engineering journals, and to prepare and distribute comprehensive and fully illustrated catalogues and specifications of their machines, indicating also the capacity of their works. Not the least important point is the desirability of taking part in all the most important competitions and other sporting events and races which will be held after the war. Undoubtedly successful competitors receive a great deal of valuable publicity, and purchases in many cases are influenced by the performances in these contests.

## *Probable Demand for Aircraft*

## *Probable Demand for Aircraft* *XIV*

PROGRESS in the aircraft industry, which was at the outset of the war a new and comparatively untested branch of engineering, has in recent years been on a prodigious scale. This progress has been accomplished by lavish expenditure on experiment and research, far greater than could have been undertaken by any commercial company. The industry will benefit, but there are some difficult problems to be solved in adapting present plant and organization for commercial construction.

Some aircraft factories are emergency establishments normally engaged in other branches of manufacture. They will probably revert to their former uses, but many firms now working under Government control will be required to do Government work after the war. Major-General Brancker is of opinion that military demands will not cease at the close of the present war. Much, of course, depends on the character of the peace terms which may eventually be concluded, but it appears certain that an island Empire must continue to maintain a powerful air fleet for defensive purposes. This can be accomplished either by maintaining a large number of purely military establishments or through the existence of a strong commercial industry capable of being utilized by the Government when necessary for national security.

It will not be a simple matter for private enterprise to build up an industry of the character required within a reasonably short time, though many schemes for commercial aeronautical developments are being discussed and plans have been prepared for regular services on international lines. There will probably not be a sufficient demand for aircraft for commercial requirements immediately after the war to absorb the output of the many establishments which will then exist. Strong, therefore, as are the objections to Government control it seems likely that for some time the aircraft industry must look to the Government for help.

Such assistance need not necessarily take the form of direct subsidy to manufacturers, but might rather be in the nature of payment for aeroplane services for carrying mails. The carriage by air of certain classes of traffic which would bear the necessary rates would be the next development, but it seems unlikely—though it is dangerous to dogmatize—that anything but slow progress will be made with public passenger services in this country for some time. Still there will, of course, be services established almost immediately, and these will probably be patronized if only for the novelty. Later will come the development of passenger-carrying machines for private owners, and in this direction the history of the motor-car will most likely be repeated, and the small aeroplane capable of carrying two or four persons and sold at a moderate price will soon command a ready and extensive sale. This would not necessarily mean any threat to the prosperity of the motor trade, which has passed from the luxury to the utility stage.

It is likely, however, that in the Overseas

Dominions and in other countries where railway facilities are comparatively restricted promoters of aircraft passenger services will at the outset find their most promising field. There are many parts of the world where railway construction cannot be justified on traffic prospects, and in such places there is a chance to establish communication by aircraft on a commercial basis. No doubt passenger services between England and the Continent will be in operation at a comparatively early date.

At present the preparation of special maps for the use of aviators is in its infancy. Major-General Brancker believes that for some time the ordinary small-scale ordnance maps in which particular objects are emphasized will suffice for all purposes. Those who are in the habit of making regular flights over the same routes soon become sufficiently familiar with the ground beneath them to know their position even under somewhat difficult conditions. Fog, of course, will always be a hindrance.

As time goes on special types of maps for the use of air pilots will be produced, and the air routes themselves be explored and charted with the object of securing the best flying conditions for particular services. Our knowledge of the upper regions of the atmosphere, where will lie the main air routes of the future, is at the present time comparatively elementary.

*The British Aircraft Industry*

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# *The History and Use of Airships*

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MAN'S early attempts to imitate Nature in the air were failures because the mechanical bird was as hopeless a proposition as were the mechanical horse and the mechanical fish.

Practically all the mediæval attempts at flight involved the use of aviform apparatus. Man did not leave the ground until he had evolved a machine which was unorthodox in character, just as he failed to produce a mechanical road vehicle until he had invented rotary motion, which is unknown to Nature.

Setting aside untold numbers of propositions which figured nowhere more evidently than on paper, the first really serious attempt made to operate a steerable balloon was that of the brothers Robert, who in 1784 produced in France a melon-shaped contrivance which supported a long, narrow car, suspended by cords attached to a net which covered the top of the balloon.

The propulsive machinery was modest—namely, three pairs of large oars formed of cane covered with silk, which were worked by hand power, being "feathered" on the return stroke. There was a large rudder at the rear of the car.

On the eventful day of the first trip, the two Robert brothers and their brother-in-law ascended, and by vigorous work succeeded in describing a curve of one kilometre radius, which showed, at any rate, that they could deviate from the feeble wind then prevailing.

So pleased were the brothers with the successful nature of their experiment that they built another airship, on similar lines, but possessing a ballonet or air-bag, for compensatory purposes.

Taking the Duc de Chartres as passenger, the brothers essayed a trip, during which they encountered an air eddy, which tore away rudder and oars and detached the air-bag from its sustaining cords so that it fell into the neck of the balloon, preventing gas escaping as it expanded. The airship attained a great altitude, believed to be 16,000 feet, and the gas had almost reached bursting pressure, when the Duc—resourceful man—drew his sword, and cut a slit in the bottom of the envelope, so saving the situation.

The Robert brothers were succeeded by a number of other experimenters, but the first airship really to do anything more was built in France by Henri Giffard. This airship had a spindle-shaped envelope 143 feet long, and 39 feet in diameter at the broadest part, and was fitted with a three horse-power steam engine and an 11-feet airscrew. A long boom was suspended from the envelope underneath, to which was attached a car containing engine, pilot, and propeller. A rudder was incorporated in the rigging.

The first trip was made in September, 1852, from the Hippodrome, Paris, when the inventor travelled at six miles per hour relativel to the air. On this airship he made severa out-and-home trips with intermediate landings.

In 1872 yet another Frenchman, Dupuy de Lôme, built a spindle-shaped airship, which was driven by an airscrew actuated by eight men turning cranks. A speed of six miles an hour was attained for limited periods.

Some ten years later Paul Tissandier built an airship with an outline similar to that of Giffard's, which was fitted with an electric motor worked by a bichromate of potash battery. The result was a speed of eight miles an hour.

A real advance was made in 1884 by Capitaine Chas. Renard, who reduced the great air resistance created by the gas envelope by making it a true streamline or fish-shape, with the rounded blunt head and tapering tail now common to the latest Zeppelins and the small British submarine-searching airships.

The method of suspending the car was one adopted by later builders—namely, to place an enormous sheet over the back of the airship, to the edges of which were attached suspensory cords, from which hung a car 108 feet long, which served the same purpose as the spar used in Giffard's airship. This method was perpetuated in later vessels of what were eventually called the semi-rigid type.

An electric motor was installed in the centre of the car, driving through a long shaft a tractor airscrew mounted in the bow of the car. The motor weighed 220 lbs. and developed 9 h.p. It was driven by a chloro-chromic battery which delivered one shaft h.p. for each 88 lbs.

The great weight of the power plant naturally handicapped the performance of the airship, which was otherwise a great success. On one occasion it flew over Paris at an average rate of fourteen and a half miles an hour.

The aeronautical successes of France naturally aroused interest in Germany, and in 1872 Hanlein built an airship of fair size fitted with a 6-h.p. gas engine, which was driven by coal gas drawn from the envelope. This fuel system, which burnt both ends of the candle, naturally restricted the inventor to short journeys, but it is said that he achieved a speed of ten miles an hour.

In 1879 Herren Baumgarten and Wolfert built an airship with a Daimler petroleum motor. A trial was made at Leipzig in 1880, but as the result of incorrect load distribution it was wrecked on the ground.

After further experiments Wolfert built another airship in 1897, but the attempt ended disastrously. The fuel tank caught fire, and Wolfert and his assistant were killed.

In 1897 an Austrian engineer named Schwartz built an airship with an envelope of aluminium, said to be 0·008 inch thick, or about the thickness of writing paper. This metal foil was arranged on some kind of metal framework. It was cylindrical in shape, with pointed ends.

Naturally it was difficult to make such a vessel gas-tight, and it very soon lost its buoyancy and was wrecked on the ground.

M. Santos Dumont will long be remembered as a pioneer both of the airship and of the aeroplane. His earlier experiments were devoted to the lighter-than-air vessel, and during a period of several years commencing in 1898 he built an extraordinary assortment of small airships.

His first experiment was with a little vessel having a cylindrical envelope of varnished Japanese silk with pointed ends, 82½ feet long and 11½ feet in diameter, possessing a capacity of about 6,300 cubic feet. It was fitted with an internal air ballonet to compensate changes of pressure, and the power plant was a 3½-h.p. motor-cycle engine weighing 66 lbs., which was attached to an ordinary balloon-basket suspended from the envelope. The poise of the vessel was controlled by moving weights. Its steering was achieved by the use of a silken rudder stretched over a steel frame.

In September, 1898, this toy airship left the Zoological Garden at Paris in the face of a gentle wind and performed all sorts of evolutions in the neighbourhood.

This first effort was followed by airships numbered 2, 3, and 4, which were modifications of No. 1. No. 5, however, was a more ambitious proposition, being 109 feet long and 17 feet in diameter. It was fitted with a four-cylinder motor, driving an enormous air-screw 26 feet in diameter, which, at a speed of 140 r.p.m., gave a thrust of 120 lbs. Among other novelties water ballast was used, and the suspension was done with piano wire instead of ordinary balloon cord.

Discouraged by general apathy towards everything concerning aeronautics, and lacking financial support from a nation of shopkeepers who would not stake money on anything which did not show prospects of an immediate profit, British aeronauts were compelled to shelve the problem of the dirigible airship almost entirely and to continue to earn their bread as parachute jumpers at country fairs. The history of the British airship in the nineteenth century can therefore be told in but few words.

The Spencer family of Highbury built two or three small ships which at times flew over London in the interests of a well-known meat-drink. Dr. Barton built a fairly large airship of cylindrical form in which bamboo of large dimensions figured extensively. This also cruised over London on at least one occasion, but ultimately disappeared into that oblivion which seems destined for the products of pioneers.

At the completion of the nineteenth century sufficient spade work had been accomplished to give students of aeronautics some idea as to the different classes into which airships would resolve themselves, and schools of opinion arose which supported the several types. It is a little difficult to give an international history of airships in precise chronological order of dates, but as the schisms in principle were almost national in character, it may be convenient to describe the different types in connection with the countries in which they most largely figured.

Roughly speaking, France may be called the home of the large semi-rigid and non-rigid airships, Germany the home of the rigid airship (essentially large); Great Britain the home of the small non-rigid, and Italy the home of the medium-sized semi-rigid.

As a matter of fact, there are exceptions to every one of these generalizations, but the arrangement is convenient.

With the arrival of the twentieth century the first really serious attempts were made in France to construct airships of a size large enough to carry a fair number of men with engines powerful enough to travel against winds of average strength.

In 1899 the Lebaudy brothers, assisted by an engineer of the name of Julliot and the balloon manufacturer Surcouf, had set to work to build a large airship, which was sufficiently successful in 1902 to warrant further experiments. Like the earlier airships, its envelope was cylindrical, and the Lebaudy brothers found the same difficulty as was experienced by their predecessors in suspending a small car from a long, narrow hull, because if the suspensory cords were to be evenly distributed along the airship's length they would naturally pull at all sorts of awkward angles and set up great compressional strains on the gas hull.

They therefore adopted the plan introduced by Giffard and imitated by Renard, and suspended a long girder below the hull, from which in its turn was suspended the car. The chief point of difference was that this girder was placed immediately under and in actual contact with the hull.

To the rear end of this supporting girder, or keel, were attached vertical and horizontal stabilizing planes and a double rudder. Elevating planes were placed above the car.

The first Lebaudy airship, the "Jaune," who took her name from her lead chromate tinted envelope, was 183 feet long, 30 feet maximum diameter, and of 80,000 cubic feet gas capacity. She was driven by twin airscrews running off a 40-h.p. Daimler motor, and attained a speed of twenty-six miles an hour.

During her first year's service this airship made twenty-nine flights, and on twenty-eight occasions returned safely to her point of departure—no small achievement. On the twenty-ninth trip, however, in November, 1902, she struck a tree and was wrecked.

A succession of Lebaudy airships was built, most of which were taken over by the French Government, notable examples being the "Lebaudy," "Patrie," "République," "Liberté," "Capitaine Marchall," "Lt. Selle de Beauchamp," most of which were still in commission at the outbreak of war.

The "République" came to a tragic end in September 1909, when her envelope was slit open by a broken airscrew and her crew were all killed.

The "Patrie" blew away from her moorings at Verdun in 1907, and disappeared into the Atlantic.

A very large Lebaudy was built in 1909 for *The Morning Post*, of which more will be said later.

As a result of the loss of the "Patrie," M. Deutsch de la Meurthe interested himself in the building of a large non-rigid airship based on the plans of Colonel Renard, and constructed by the Astra Company, of Levallois-Perret, in association with M. Clément, the famous motor builder.

He placed this airship at the disposal of the French Army. She was 200 feet long, and displaced 120,847 cubic feet. She had a vertical and horizontal empennage (or fin arrangement aft) formed of cylindrical gas chambers added to the end of the tail, and a long open fuselage or car containing engines, fuel tanks, and crew, and hanging 30 feet below the envelope. She was named the "Ville de Paris."

The "Clément-Bayard" was next produced in 1909 with various improvements. She was followed by "Clément-Bayard II" (1910), "Dupuy de Lôme" (1912), "Adjudant Vincennot" (1912), "Clément-Bayard V" (1913), "E. Montgolfier" (1913), "Clément-Bayard VII" (1914), and "C.-B." VIII and IX (building 1914).

A series of vessels were built to the designs of a Spaniard, Señor Torres, by the Astra Company, from 1909 onwards, which were consequently known as the Astra-Torres type. These airships, although of the non-rigid principle, were distinctive in that their transverse section was not circular, but resembled the outline of a trefoil window—namely, a series of three circles arranged with their centres at sixty degrees in relation to each other, and with their edges intersecting, with the result that the whole envelope had the appearance of a bunch of three bananas, one above and two below.

This section was found to give great strength, and it was found convenient to anchor the suspensory cables to the two ridges near the top of the envelope, which caused them to fall at a much better angle than if they had been attached at the line of greatest diameter of the hull.

From these two longitudinal ridges of attachment the cables were led down through the inside of the envelope, out through its base, via stuffing-boxes, and so to the cars.

These ships were very fast and successful, 800-h.p. models with two cars and four engines being used during the war.

Mention must be made of the series of Zodiac airships, constructed first for pleasure, and afterwards for military purposes. Ranging from a small vessel of 49,300 cubic feet with one 45-h.p. motor, to large craft of 810,000 cubic feet with four 250-h.p. motors, their various performances made them suited to a variety of uses.

Another interesting airship was the "Spiess," a French rigid, constructed of timber by the Zodiac Company. Compared with her contemporary Zeppelins, she was but a qualified success.

The first Zeppelin was produced at Lake

Constance as early as 1900. The principles on which she was constructed remain good to this day, the only alterations being detail improvements, refinements in outline, and increase in size, weight, horse-power, and consequently in speed and carrying capacity.

Essentially, a Zeppelin is a cylindrical aerostat, constructed of an aluminium girder-work frame covered with fabric, which contains a series of independent cheese-shaped gas chambers arranged more or less like peas in a pod.

To the rear of this hull are attached the necessary stabilizing and control surfaces, such as fins, rudders, etc., and suspended from its keel girders are two, three, or four cars, containing crew and engines, and advantage is taken of the triangular nature of the keel girders to construct a passage therein, wherein fuel tanks may be stored. This serves also as an alley of communication between the cars.

It will be seen that whereas the non-rigid and semi-rigid airships depend for the preservation of their contours upon internal gas pressure, the Zeppelin preserves an indeformable outline even if the gas in its hydrogen chambers is at no greater pressure than that of the atmosphere. A great deal of otherwise necessary complication in the nature of internal air ballonets is obviated thereby.

The first Zeppelin was of 400,000 cubic feet capacity and weighed nine tons. Driven by two 16-h.p. motors, and carrying only five men, she could not be called efficient, but her first trip lasting one and a quarter hours at 4,000 feet was encouraging, and rebuilding was commenced. The airship reconstructed, and now called No. 2, came forth in November, 1906, fitted with two 85-h.p. Daimler engines. She was promptly wrecked in her trials.

Not discouraged by the loss of nearly six years' work, Count von Zeppelin continued to build ship after ship, selling perhaps one to the German Government and possibly losing the next two on trial trips.

A passenger fleet was established and many wonderful voyages were accomplished exceeding a thousand miles in length. After periods of disaster public subscriptions were raised.

Occasionally von Zeppelin was in disgrace with those in power, but quickly the storm blew away and all was well.

Most of the troubles were due to the difficulties of handling so large a craft when on the ground, and a forced landing away from home almost necessarily spelled ruin, for lack of skilled landing parties and housing accommodation.

The war history of the Zeppelin is well known. As a naval scout she has been, and is still, of high value, and until her most vulnerable points were assailed by aeroplanes she was a redoubtable bomb dropper.

The modern Zeppelin has changed somewhat from her immediate predecessors. Her hull is no longer a symmetrical cylinder with rounded ends, but a good streamline fish-shape. The cumbrous airscrews and their complicated brackets have been removed from the sides of the hull and mounted direct on the motors.

In addition to two large cars arranged on the longitudinal axis, there are now two small side cars each containing an engine and airscrew. The number of 260-h.p. Maybach motors has been reduced from six to five, resulting in greater buoyancy and the ability to rise to 20,000 feet if need be. For the same reason the armament has been reduced considerably.

Apparently the speed and radius of action of these craft remain as they were in 1914—namely, about 500 miles at sixty miles per hour.

Notwithstanding their profound faith in the Zeppelin, the German aeronautical engineers did not neglect other types. From 1907 onwards a series of non-rigid airships on Lebaudy lines were constructed for the Government by Major Gross, and a series of non-rigids of considerable size were built by the Parseval Company at Berlin. The most notable feature of this type was the arrangement of all the controlling planes on the envelopes, there being no rudders or elevators attached to the small car, which hung at a considerable distance beneath the envelope.

The big airships built by the Schütte-Lanz Company at Mannheim were interesting because of their rigid hulls constructed of timber girders instead of the metal frame found in the Zeppelin. The form of the Schütte-Lanz always presented a better streamline than that of the Zeppelin, and the airscrews were invariably attached to the sterns of the cars, and were not attached to the side of the envelope.

There is no evidence that the Schütte-Lanz is still being built, but the modern Zeppelin clearly borrowed many of its features.

The history of the British airship is remarkable as a record of good work done under difficult and discouraging conditions of penury.

The first year or two of the twentieth century were only noteworthy for the continued work of Dr. Barton and the Spencer family already mentioned. Then came the pioneer work of Mr. E. T. Willows, of Cardiff, who commenced operations in 1904 and constructed a series of very small airships comparable with those of M. Santos, and the now familiar "Blimp" or submarine scout (S.S. type).

The first example of the Willows airship was a semi-rigid with an envelope of heavy

Japanese silk 74 feet long and 18 feet in diameter. The nacelle underneath was 45 feet long and was constructed of tubular steel. There was a 9-h.p. twin Peugeot motor which turned a ten-foot airscrew at the stern and a pair of airscrews in front, which were used to control the airship by varying the angle of their shafts so that they could pull forward, or upward, or downward. These propellers were the subject of a patent, which was afterwards appropriated by the Government.

As the result of experience derived from flights with this airship Mr. Willows built two more nacelles, or car units, which were bought by the Army Balloon Factory in 1908.

In 1909 he produced a small semi-rigid single seater with twin airscrews in which the aforementioned swivelling invention was employed. The envelope was eighty-six feet long, and there was a 30-h.p. J.A.P. motor, and on this craft he navigated from Cardiff to London.

In 1910, the same airship rebuilt flew from London to Paris, carrying Mr. Willows and a passenger.

The first Government airship was built at the Army Balloon Factory at Farnborough. It was an extraordinary structure, with an envelope exactly the shape of the type of breakfast sausage erstwhile called "German," built up of tens of thousands of goldbeater's skins cemented together in fifteen layers. The protective varnishing was inadequate, with the result that early in its trials this first airship, which bore the modest name of "Nulli Secundus," became soaked with rain and was wrecked.

A bigger airship of exactly the same shape was then built, which, fitted with a 100-h.p. engine, was supposed to do forty miles per hour. In October, 1907, "Nulli Secundus (II)," jestingly called by *Punch* "Nulli Tertius," flew from Farnborough to London, failed to return, and stopped at the Crystal Palace, where she broke away from her crew and was wrecked.

Early in 1909 the factory turned out a small airship called the "Baby," fitted with two 12-h.p. motors, which had a fabric fish-shaped envelope and a long car, something like an aeroplane fuselage, which contained crew and engines, and carried the control planes.

Considering her small size this ship was quite successful.

Later a larger vessel was built, not unlike a Clément-Bayard, 154 feet long with a car 84 feet long. It had an 80-h.p. Green engine, driving two propellers, which swivelled in the manner set forth by Mr. Willow's patent. Colonel Capper, R.E. (now General), and the late Lieutenant (afterwards Lieutenant-Colonel) Waterlow, R.E., were chiefly concerned with her construction and navigation.

In 1910 a new airship of small size was built, known as the "Beta." She had a 30-h.p. Green engine, and the long nacelle was retained. She flew from Farnborough to London at night, carrying Colonel Capper, Lieutenant Waterlow and the late Mr. T. Ridge, who afterwards was killed on the first Royal Aircraft Factory aeroplane. A second successful trip to London was performed in daylight with a safe return.

A larger airship in the meantime had been built known as the "Gamma."

She was succeeded by the "Delta" and the "Eta."

An imported addition was made in 1910 in the shape of an enormous Lebaudy, bought with subscriptions from readers of *The Morning Post*, which flew from France to Aldershot, covering 197 miles in five hours and twenty-eight minutes, being unfortunately somewhat damaged at the end of the trip when entering her shed. Repairs were not effected until May, 1911, when she was wrecked on her next flight through mishandling when attempting to come down.

A Clément-Bayard was also bought from France, chiefly as the result of political pressure, but she too suffered an obscure end.

In the meantime, the Admiralty, who were somewhat alarmed at the successes of the Zeppelin, laid down a large airship at Barrow of the rigid type, which after many delays was handed over untested in September, 1911. Her name, the "Mayfly," was unfortunate, because she did not fly. On the first attempt to bring her from her shed for flying tests she broke her back against the entrance and was ignominiously dragged back to emerge no more.

The most notable feature of this airship was that she more nearly resembled the modern Zeppelin than her contemporary Zeppelins, possessing a much better streamline, and having her stern airscrew driven direct from the engine.

In the early days of Army airships they were maintained by the Army Balloon Factory. Upon the creation of the Royal Aircraft Factory they were handed over to that institution, but at the end of 1913 they were all handed over to the Navy, which has controlled them ever since.

The airships then existing were the Gamma, Delta, and Eta, to which were added a German Parseval and a French Astra-Torres, which constituted our airship fleet on the outbreak of war. The two last named ships did fine patrol work in the Channel during the first months of hostilities.

Since that date Naval airships have been built in considerable numbers.

Every one is familiar with the small

" Blimps," officially known as " S.S." (submarine scouts). These were originally constructed by attaching small airship envelopes to the fuselages of obsolete aeroplanes, the wheels, skids, engine, airscrew, rudder, and elevator retaining their original places and functions. Now special nacelles or cars are built for these small craft, the best of which show a good performance.

The original Astra-Torres has been reproduced with modifications and improvements, and is officially known as the " C.P." (coast patrol) type.

There is no doubt that, so far as this country is concerned, the medium-sized airship has proved most successful, and from time to time it has been officially stated that considerable execution has been done to enemy submarines by our lighter-than-air patrols.

From 1908 onwards Italy took a practical interest in airships to an important degree, and during the present war they have done some very successful bombing work.

The earlier productions were small non-rigids with rather elaborate tail planes mounted on the stern of the envelope. They were called variously P. type and M. type and were fitted first with French and later with Italian built engines.

By 1914, another type, the Forlanini, a semi-rigid of large size, had been commissioned, and since then this type has predominated. A large enclosed girder is built like a keel underneath the envelope, the front of which forms the navigating cabin : the midship contains engines and tanks, and the rear serves as a support for the stabilizing planes. The airscrews and control project from the sides of the girder towards the stern, being supported on brackets.

In addition to these home-made airships Italy acquired one or two of the German Parsevals in peace time.

As regards other foreign Powers, there is little to be said. Russia owned various French and German made airships, and Turkey had a Parseval or so.

The minor European Powers have from time to time dabbled in airships, but have achieved little.

Taking it all round, the airship has played a fairly useful part in the war, having achieved rather less than was hoped by its supporters, and a good deal more than was expected by its critics.

As regards its commercial possibilities one cannot hazard much beyond guesses. Before the war some three or four Zeppelins, helped by Government subsidies, carried many thousands of passengers without accident for what would now be called "joy-rides." It is possible that when peace comes similar services will come into operation, for probably many people will trust the bulk of an airship, in preference to the comparative insignificance of an aeroplane, for their first experience of aerial travel. Careful organization, proper arrangement of harbours, and skilful navigation may even make pleasure airships a commercial proposition. But as mail carriers they have little prospect, for the speed of the best airship has always been only half that of the best contemporary aeroplane.

Further chemical and physical discoveries may, however, so improve airships as to make them practical vehicles, and therefore one does not venture to disbelieve entirely in their commercial future.

*The British Aircraft Industry*

# *British Kite Balloons and Parachutes*

## *British Kite Balloons and Parachutes* *XVI*

ONLY those officers who have been on active service in any of the war zones can appreciate the influence kite balloon sections of the Army and Navy have had upon the conduct and direction of this war. They have been rightly termed " the eyes of the services," and have proved invaluable in this respect.

The outbreak of war in 1914 found the British Army without observation balloons, other than the old-fashioned " spherical," whilst the German and Austrian Armies were fully equipped with large numbers of kite balloons of the " Drachen " type. These were flown extensively on their various " fronts," giving the enemy a great advantage, and enabling them to secure valuable information as to the movements of our troops and the positions of our artillery. It was left to the naval branch of the Air

Service to recognize the merits and military value of this type of aircraft, and credit for introducing the kite balloon to the British Army and Navy is undoubtedly due to the following officers of the R.N.A.S.: Wing Captain E. M. Maitland, Wing Captain E. A. Masterman, Wing Captain Mackworth, and Wing Commander Delacombe, who towards the end of 1914 agreed that the matter was of very great urgency, and decided to advise that kite balloons should be immediately provided for the British Air Services.

The French Army, which was also without observation balloons, was able to obtain balloons from the well-known establishments of the "Zodiac" and "Astra" Companies, of Paris, firms noted for their large and well-equipped aeronautical factories. They had a good supply of suitable fabric available, and for some months in the early part of 1915 the British obtained several balloons of French manufacture through the courtesy of the French Government.

The Admiralty entrusted the work of constructing the first British-built kite balloon to the old-established firm of C. G. Spencer and Sons, the principal of which is Mr. A. C. Spencer, the senior survivor of the celebrated pioneer family of aeronauts. Fortunately, this firm was in possession of certain information concerning the German-built kite balloon, which was amply supplemented by details secured by the managing director, who, in company with the officers previously mentioned, carefully inspected a German-built balloon in use by the Belgians on the Western Front, and thus obtained important up-to-date information, which proved to be of the very greatest assistance.

The British aeronautical firms quickly got into working order, and, supplies of fabric becoming more plentiful, Airships (Limited), Vickers (Limited), and J. Mandleberg and Co. (Limited), of Manchester, in addition to Messrs. Spencer and Sons, already mentioned, began manufacturing kites in fair numbers, so that it became unnecessary for the Army or Navy to requisition further supplies of balloons from France.

The first obstacle was the supply of a suitable fabric. The only British firm with a knowledge of balloon fabrics at that time was the North British Rubber Company, of Edinburgh, who were then fully engaged in the manufacture of airship cloths, but ultimately the Victoria Rubber Company (Limited), of Edinburgh, succeeded in producing a proofed fabric, from which the first British kite balloon was manufactured.

At a later date the Ioco Proofing Co. (Limited), and Messrs. J. Mandleberg and Co. (Limited), I. Frankenburg and Sons (Limited), and Chas. Macintosh and Co. (Limited) produced high-class balloon fabrics, which are now used in large quantities.

Besides the balloons themselves the equipment of a kite balloon section comprises numerous items, such as valves, baskets, steel cables of very high tensile strength, speedy motor-driven winches, hydrogen gas-making plant and cylinders, various aeronautical instruments, parachutes, as well as many articles very necessary to complete the outfit, all of which have to be provided under great stress.

In times of peace the creation of a new

industry presents a number of difficulties which are multiplied infinitely under war conditions, but the rapid development of kite balloon manufacture has been one of the marvels of the war. This has only been made possible through the extensive pioneer work and enterprise of private manufacturers, who, with their highly skilled staffs and well equipped and organized establishments, have been enabled to interpret the wishes and requirements of the Air Department correctly and promptly.

Credit must be given to the officers of both services, who have shown keen energy and perseverance, often under adverse circumstances, whilst the equipment officers have surmounted almost superhuman difficulties, and both they and the constructors have received invaluable help from men who have gained experience whilst on active service with the Kite Balloon Section, or whilst working in the various aeronautical experimental laboratories and departments at home.

The kite balloons now used by the Air Services are the "Streamline" type, the invention of Captain Cacquot, of the French Air Service. They are very graceful, and are remarkable for steadiness when flying at great heights in very strong winds. These balloons are gradually becoming standardized, so that they can be manufactured quickly and uniformly. It is a matter for sincere congratulation that Great Britain can produce all materials required for these balloons.

All interested in the " K.B." express great satisfaction that the Air Board have amalgamated the R.N.A.S. and R.F.C. Kite Balloon Sections, with Wing Captain Mackworth at the head of the Technical Department and Supplies.

From the inception of the kite balloon as a valuable military asset this officer has been associated with its management and construction ; in pre-war days he was attached to the R.F.C., and is an authority on ballooning, and widely known as a skilled aeronaut. This important branch of the Air Service is, therefore, in very capable hands, and efficiency of control must result.

When Professor Baldwin, the celebrated

American aviator, created a sensation in England in the early eighties by making a number of parachute descents, it was not anticipated that at a later date the art of parachuting would become a branch of military aeronautics, and that large numbers of British officers would be making parachute descents within the war areas with almost clockwork regularity.

The pioneers of the parachute in England were the celebrated aviators, the Spencer brothers, all of whom have been engaged since their boyhood in making parachute descents at fêtes and galas throughout the world and undoubtedly hold a unique record in this respect.

In 1913 Wing Captain E. M. Maitland, of the R.N.A.S., at that time attached to the R.F.C. at Farnborough, interested himself in the parachute and its application to military aeronautics, and approached Messrs. C. G. Spencer and Sons, who made a parachute for him, which was packed in a case or cylinder to be attached to an airship gondola or a balloon basket. Early in 1913 Captain

Maitland made a descent from the British Army airship "Eta" in the neighbourhood of Farnborough. Since that date this officer has made several descents from balloons and airships, and it was solely through his foresight that the value of the parachute as a life-saver was recognized and quickly adopted by the British Air Services. All British kite balloons and airships are now equipped with sufficient parachutes for the pilots, and the large number of officers who have made safe descents in the different theatres of war amply testifies to the large margin of safety provided in the present types of parachutes in use and their necessity as a part of the Balloon Section's equipment.

Parachuting under war conditions cannot be compared to the very simple performance of making a descent at a summer fête or gala in peace time, and the possibility of a sudden attack on the balloon by a German aviator makes it very necessary that the balloon pilot shall be ready to make his jump at short notice, and often quite unexpectedly.

He must necessarily be very cool, and the few accidents which have occurred have undoubtedly been caused by the exceptional angle taken by the balloon when it bursts into flames after being attacked, or by the inability of the pilot to clear himself from the balloon car and rigging, resulting in a nasty fall unaided by the parachute.

The two types of parachute used by the British Air Services are the "Spencer" and the "Guardian Angel," the latter being the invention of Mr. E. R. Calthrop, the well-known railway engineer, and it is undoubtedly a compliment to the British designers that the French Army now use the "Spencer" type, which our enemies have also copied. The Germans, however, are compelled to use a very inferior cotton fabric, whilst the Allies still continue to manufacture them from the very highest class of materials.

Parachuting from an aeroplane presents many difficulties, and although a large number of inventors have endeavoured to create a suitable parachute for this particular work, the results obtained hitherto have not been satisfactory, by reason of complications arising through the many types of machines in use and the difficulty of taking the pilot out of the falling aeroplane. The celebrated French aviator Pégoud was the first aviator to descend from an aeroplane with a parachute.

*The British Aircraft Industry*

*The Law of the Air*

## *The Law of the Air*

## *XVII*

THE development of aerial transit within the last few years has given rise to a number of questions which will call one day for answers in our Courts of Law. So far the employment of aircraft has been confined mainly to military purposes, but the time cannot be far off when journeys which are now made by railways and steamboats will be undertaken in aeroplanes. Goods, especially perishable commodities, will be transported in large air vessels and special mail services may be established. Should such things come to pass there will be need for a rapid and curious expansion of the English Common Law and also for legislative measures of a revolutionary character. At present the law reports contain but a scant reflection of the world's evolution in the domain of the air. Legal recognition of aerial operations has been demanded mostly in insurance disputes about the liability for damage done by hostile aircraft. Nothing has yet been said on the question as to how far the use of this new medium for commerce and even pleasure will affect the ancient legal rights of the owners of the soil.

There is a venerable maxim of the law that he who owns the land also owns everything above it—*cujus est solum ejus est usque ad cœlum*. But this is an archaic generalization which has been limited by various judicial interpretations and is likely to be subjected to much modification within the next few years. A man's rights to the possession or the enjoyment of his land may be violated either by trespass or by nuisance. The trend of legal opinion has been setting strongly against the theory that there can be a trespass upon the "insubstantial" air. As early as 1815 Lord Ellenborough in one of his judgments was prophetic. The action was brought for a trespass by the defendant in allowing a board to overhang the plaintiff's premises. Lord Ellenborough said: "If this board overhanging the plaintiff's garden is a trespass, it would follow that an aeronaut is liable to an action of trespass *quare clausum fregit* at the suit of the occupier of every field over which his balloon passes in the course of his voyage." He took the view apparently that there must be material contact and he added, as an illustration, that he was not prepared to hold that if a man fired a gun across his neighbour's field a trespass had been committed if the shot did not touch the land. In this view, which, it must be admitted, has not been unchallenged, no action for trespass would lie if an aeroplane passed over a man's land, unless the aeroplane actually struck the land, or the houses, or the trees upon it. It is probable that Lord Ellenborough's opinion will prevail in spite of later criticisms, because it goes in the direction of making the Common Law adaptable to the circumstances of a progressive community.

There is, however, another aspect of the position. Although the theory that a man may resist a "trespass" upon the column of air above his land may disappear, there is no likelihood that actions for nuisance caused by aerial navigation will cease to be defended with success. It is possible that the low flights of aeroplanes by day and night across a farm might seriously interfere with the breeding of stock or might produce disastrous results by terrifying and stampeding horses and cattle. In such an event the owner would undoubtedly have a remedy by way of an action for nuisance. It has long been held that such an action would lie if a man so used his own land as to cause the air which passed over his neighbour's land to be noxious and harmful. Thus, the proprietors of an aerodrome would, no doubt, lay themselves open to an action for nuisance were they to occupy the air passing over adjoining grounds with low-flying aircraft which caused constant noise and vibration. Injunctions have been granted and damages awarded to plaintiffs who had suffered serious injury to health and business from great and intolerable noise.

So much for the effect of the Common Law. The legislature has already placed upon the Statute-book two measures dealing with this subject—the Aerial Navigation Acts, 1911 and 1913. The Act of 1911 gave the Home Secretary power to prohibit the navigation of aircraft over certain areas "for the purpose of protecting the public from danger." The later Act was passed to extend the Home Secretary's powers by enabling him to make aerial navigation orders for the safety and defence of the realm. He was given authority to prescribe the areas within which aircraft coming from places outside the kingdom were to land, and to appoint officers to signal to such aircraft and to fire upon them if they failed to comply with the signals. Orders were made accordingly prohibiting the navigation of aircraft of every class over certain areas and of aircraft coming from abroad over the whole of the coastline of the United Kingdom, except some scheduled parts. It was made necessary for any person in charge of an "airship" abroad to obtain "a clearance" from a British consular officer before starting on a voyage to this country. Details had also to be supplied, such as the time and place of departure, the type of the airship, the nature of the cargo, the proposed destination and the object of the voyage. The carriage in aircraft of photographic apparatus, pigeons, explosives, firearms, and mails was forbidden.

These statutes were obviously groping and tentative, and the difficulties of drafting orders under them were considerable. In 1911 and 1913 aviation was little developed as compared with what it is to-day. The regulation of aerial traffic can hardly await a tardy expansion of the Common Law. It is almost certain that Parliament will insist upon a statutory recognition of "freedom of the air" for all subjects of the king, leaving to those who abide on the earth merely the right to obtain injunctions and damages for nuisance where airmen become audacious and over numerous. Actions for personal injuries and for damage to property through accidents, such as collisions, in the air will also bring a new form of litigation into the courts, and will demand various and interesting decisions on the law of negligence.

*The British Aircraft Industry*

## *American Plans*

AN interesting statement has recently been issued by the U.S. National Advisory Committee for Aeronautics in connection with the plans of the new Civil Aerial Transport Committee. As showing that other countries will be "up and doing" it should act as a stimulant to the British Government. The report reads in part as follows :—

The future of aviation is of vital importance even at the present time, because upon it depends very largely the future of the thousands of men now going into the air service, the millions of dollars allotted to it by Congress and by industry, and, in general, the possibility of salvaging the present investment in aviation expressed in terms of human energy, skilled workmen, trained aviators, time, and capital.

What, for instance, are we going to do after the war with the thousands of fliers and of planes on hand, with the factories tuned up for vast quantity production, and with the great training schools and fields, with their capacity for turning out aviators? So far as humanly possible, plans should now be laid looking toward the utilization of all these as the nucleus of a future aviation development which will serve to open up a new avenue for man's activities and enormously widen his vision and capacities.

Peace will find this country with an immense air capital on hand comprising skilled workmen, factories, machinery, and industrial organization in effective operation. This capital must be so conserved and directed that, if possible, not a man nor a dollar will be wasted in the hiatus between war and peace. The situation at the termination of hostilities must be foreseen so far as humanly possible, and plans laid in advance, in order that we may then avoid hasty and ill-advised measures.

Europe has already gone a long way in such provision. Aviation there is almost as old as the war, and is, in a sense, bred into the bone.

The moment the war is ended there will be ready a complete plan for the conversion of all this equipment to the uses of peace and commerce. France set up such a committee, and England followed shortly afterwards. One of our first steps, of course, has been to get in touch with the Allied Committees in order to secure the value of their experience and to plan for the complex international phases of the situation.

One of the most important of the many problems pressing for consideration is the human one of what is to become of our airmen. Not only will these men deserve well of their country, but in self-interest the country must safeguard a skill which is both rare and costly. They not only deserve opportunities for further service in peaceful vocations, but it is an economic necessity that they should have the opportunity of continuing to serve along the lines which will secure some return on the national investment which they represent. There will be many such lines of service, whether in the army, in aerial mail, coast guard, air policing, scientific investigation, or in the training of new aviators.

The new industry also which has grown up under Government inspiration should be protected against sudden stoppage of war orders. If when peace comes a few months were allowed to pass without new business, the industry which has been built up with such care would be seriously crippled. The vast army of workmen required under present conditions would be thrown out of employment and forced to seek opportunity elsewhere, thus adding to the industrial confusion which must be anticipated in the readjustment between war and peace. One of our problems will be to find means of minimizing the ill effects of such readjustments, possibly by having plans for peace planes for mails, coast guard, policing, and mapping so up to date that when war orders stop the industry may change over with the minimum disturbance to the more permanent work ahead.

The first and more obvious use of aeroplanes in the future lies in the delivery of mails. Already Congress has appropriated $100,000

(£20,000) for the initial step in aerial delivery, but for the present all manufacturing energies must go into the war planes. However, the War Department has agreed, subject to Congressional approval, to turn over all planes no longer adaptable to military use to the Post Office as a beginning of its air service. In view of the numbers which may be so transferred later, it is essential to lay plans without delay, as is being done by the Post Office Department, for the specific routes, the aerodromes, quarters, *personnel*, etc. Abroad, both France and Italy have developed aerial mail service in a preliminary way to great advantage. The possible achievements of aeroplanes in speed and distance seem to be limited only by the imagination.

## *Looking Forward*

AS the coracle was to H.M.S. *Queen Elizabeth* so will the modern aeroplane be to flying machines of ten, fifteen, or twenty years hence, for, under the stimulus of war and the economic conditions which will prevail, as a necessary consequence of the war, evolution in aerial navigation will probably be fifty to one hundred times as rapid as was the evolution of maritime navigation.

The development of aviation is limited by one factor only, the reduction in the weight-horse-power ratio of the engine or power unit.

Along what lines the power unit will eventually develop no man can say. Only one thing is certain, and that is that more and more power will be obtained at a less and less cost of dead weight. It is certain that the near future will see a marked improvement in this respect in the present type of engine, but one can only speculate as to the form power units may eventually assume.

For instance, if a turbine internal combustion engine is ever evolved which represents a corresponding improvement in power for weight which the steam turbine gave over the reciprocating steam engine, almost limitless possibilities are immediately opened up. Again, who will say that a high-explosive engine, with T.N.T. or dynamite or cordite as a fuel, is impossible of realization?

The substitution of gun-cotton for petrol would represent no such difference in principle as did the transition from steam to petrol. The machine-gun and modern quick-firer is, in effect, a high-explosive motor and may well prove the genesis of the H.E. aero power unit.

That the future will see the evolution of power units embodying entirely new principles is quite certain. What form the new engines will take, or how soon they will make their appearance it were idle to speculate. Existing types may reach their limit of development; the alternatives suggested above may be brought to great perfection, or new methods may make their appearance at any time and entirely supersede old ones.

Even with the present engine and its immediate successors the development will be amazingly rapid. A single year may see the general use of a 1,000-h.p. or even a 1,500-h.p. aero engine, and there would appear to be no valid scientific reason why far greater increases in power should not take place.

So far as the aeroplane is concerned the multiple-engine machine has come into its own, and two-engined machines having proved so successful, why should there not be six, twelve, or even twenty-engined machines? For military purposes there are many and serious objections to such leviathans. To mention a few obvious disadvantages, they would be unhandy; would present too large a target, and would require too large aerodromes. For civilian purposes, however, the very features which make them undesirable for warfare would be regarded as assets. Stability and safety increase as manageability decreases, and the former will be most needed when the aeroplane is applied to commercial uses.

The coming of a new type of power unit of very low weight-horse-power ratio will be accompanied by radical changes in the machine itself. The first and most certain development will be the passing of the aeroplane—to the extent that the word premises the possession of planes or wings—and the advent of the helicopter.

In the early aeroplane, whose engines were relatively heavy for the power they gave, the entire work of lifting the machine was thrown upon the wings.

To-day aeroplanes tilt their tails down and derive a substantial percentage of their lift direct from the pull of the airscrew. It is only a question of a little more power and a little less weight in the engine before the wings are dispensed with altogether and both vertical or horizontal direction obtained from the airscrew alone.

The helicopter—which, it may be noted, was predicted by the imaginative writers of the past before the principles of the aeroplane were conceived—will possess one great advantage over its predecessor. It will be able to stand still or hover in the air. It will, moreover, be able to move in any direction in the horizontal plane, while at the same time ascending or descending. It will be independent of atmospheric conditions. Its engines will be silent, and it will be capable of travelling at enormous speed out of sight from the ground.

The first objection which will be raised to the helicopter is that it is solely dependent on its engines, and cannot glide, and an engine failure will mean a certain crash. This, again, depends solely on the weight-horse-power ratio of the engine. Given a sufficiently low ratio it will be possible to have one, two, or even more spare engines.

It is no wild flight of imagination to predict a machine capable of vertical flight to 40,000 feet, at a speed of 100 miles an hour, and a horizontal flight at 200 miles per hour simultaneously—or the maintenance of a height of 40,000 feet and a horizontal speed at that height of three to four hundred miles an hour.

Such altitudes and speeds will bring with them, of course, their own problems for the pilot and crew. Indeed, the relatively insignificant heights and speeds of which aeroplanes are even now capable have called for the provision of aid to nature in the form of oxygen breathing apparatus and electrically heated clothes, guns, etc.

It has not yet become absolutely necessary to heat the engine, but we have progressed so far in the direction as to provide shutters to prevent the radiator from functioning in certain circumstances.

The next necessity will probably be an artificial atmospheric pressure for the crew and an artificial atmosphere for the engine —if the latter maintains the present general principle.

A *sine qua non* of an artificial atmosphere will be an airtight cabin or fuselage for the crew, and this will have to be insulated against the intense cold of the outer air. As the cabin will have to be streamlined, it is possible even to venture a prophecy as to its form and construction. It will probably be in the form of an inverted pear, with an outer case or skin of aluminium, insulated from the inner skin by a vacuum. If propulsion is obtained from a single airscrew it will be necessary to have spiral vanes round the outer skin to offset the torque from that screw.

It is well known that the laws governing motion through the air are very similar to those controlling motion through water. At the stage of its development indicated above, it will be seen that the helicopter will possess all the essentials of a submarine, as well as of a flying machine.

There would appear to be no valid scientific reason why it should not become completely amphibious and constitute a "flying-submarine" in very fact.

Another problem which will undoubtedly be solved sooner or later is the wireless transmission of energy. This will have a tremendous influence on aviation, and one of its first results will be the elimination of the pilot and crew altogether. The future may see the projection, through the skies and on or under the seas, of vast quantities of merchandize or war material, controlled by a man on the ground at a keyboard.

That the flying machines of the future will be armoured and armed with heavy guns is certain. Also, they will be equipped with wireless telephones, through which they will be able to speak to any place within one hemisphere. Their carrying capacity will enormously increase; also, the precision with which they are able to drop bombs will undergo marked improvement. Bomb-dropping to-day is in about the same stage of development as artillery was at the battle of Cressy. The difference between the accuracy and weight of the guns then used and modern 17-in. guns may be expected to be the measure of difference between bomb-dropping of to-day and of a few years hence.

One of the chief difficulties of accurate bomb-dropping to-day occurs in calculating the exact horizontal travel of the bomb between the aeroplane and the target. A helicopter which could stand still over its target would not have this factor to contend against.

At first sight it would appear that the flying machine is destined to compel humanity to revert to cave-dwelling, or to consider seriously the desirability of arresting further progress in aviation, after the war, by international agreement. To adopt the latter course, however, would be to abandon faith in human ingenuity, which will, unquestionably, devise schemes and methods of defence to keep pace with the offensive power of the aviator. The history of the gun and the armour will recur, and neither the invading airman nor the defending forces will ever establish permanent and complete ascendancy over the other. As the day of the Zeppelin came and passed, so will the day of the Gotha disappear, and so with all the innumerable other types of flying machines that posterity is destined to know.

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